DOCUMENT RESUME

ED 279 520 SE 047 787

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TITLE Science and Mathematics Education in the General Secondary School in the Soviet Union. Science and Technology Education Document Series No. 21.
INSTITUTION United Nations Educational, Scientific, and Cultural Organization, Paris (France). Div. of Science, Technical and Environmental Education.
REPORT NO ED-86/WS/81
PUB DATE Jul 86
NOTE 205p.; Drawings may not reproduce well.
AVAILABLE FROM Unesco Press, 7 place de Fontenoy, 75700 Paris, France.
PUB TYPE Reports - General (140)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Annotated Bibliographies; *Biology; *Chemistry; Foreign Countries; Mathematics Education; National Programs; *Physics; Science and Society; *Science Curriculum; Science Education; *Science Instruction; Science Materials; Secondary Education; *Secondary School Science
IDENTIFIERS UNESCO; *USSR

ABSTRACT

Developed as part of a document series in UNESCO's Science and Technology Education program, this volume reviews the major trends and cites the improvements in the natural science and mathematics education in the Soviet Union. Separate units are provided for the discipline areas of mathematics, physics, chemistry, and biology. These sections contain such information as: (1) the content and structure of the course; (2) recent trends; (3) the role of the course; (4) methodological features; and (5) essential knowledge areas and skills. Illustrations and an annotated bibliography follow each unit. (ML)

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Science and Mathematics Education in the General Secondary School in the Soviet Union

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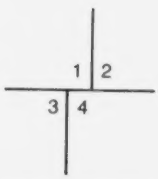

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Science and Technology Education

Document Series No. 21

Science and Mathematics Education in the General Secondary School in the Soviet Union

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Education**

ED-86/WS/81

UNESCO

Paris, July 1986

PREFACE

School science and mathematics programmes are undergoing revisions throughout the world. In some science areas, there is consensus on what should be included in the curriculum, while in others, there is none. For this reason, Unesco finds it useful to present the efforts of one country, the U.S.S.R., to modernize the teaching of science and mathematics.

This is the twenty-first volume in a document series initiated as part of Unesco's Science and Technology Education Programme with the aim of encouraging an international exchange of ideas and information.

Unesco wishes to thank the authors and the National Commission of the U.S.S.R. for Unesco for preparing this document.

The views expresed in the text are those of the authors and not necessarily those of Unesco.

The material for this document was prepared several years ago before the new reforms of the Sovietic school system of education had occurred. During the preparation of the final version of this document, Unesco Secretariat made several technical changes in its presentation, such as including relevant annexes after each theoretical unit.

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Universal compulsory secondary education in the USSR is guaranteed by its Constitution as adopted by the Supreme Soviet in 1977.

Children enroll in secondary school at the age of 7 and continue studying there for a period of 10 years, completing 10 grades*. All of the basic natural science, mathematics and humanities subjects offered in USSR secondary schools are compulsory for all pupils. These subjects include mathematics, physics, chemistry and biology.

On completing the eighth grade, pupils who wish to do so may transfer to secondary vocational technical schools or secondary specialized educational establishments. All of the types of secondary educational institutions in the USSR maintain a single unified level of instruction in general subjects. Graduates of all of the different types of schools enjoy an equal opportunity to continue their education in any higher educational institution to which they may wish to apply.

The accessibility to learning for all secondary school pupils is ensured by providing for the intellectual and physical development of the schoolchild in the course of the learning process. One of the means of making sure that the pupil makes intellectual progress is the step-by-step structuring of the subject matter.

This step-by-step structuring facilitates the attainment of a number of goals set for and by Soviet schools, namely:

- compulsory correspondance of subject matter to age-related interests and level of psychological development of the child;

- the shaping of a scientific world outlook in line with age-related ability and cumulative life experience;

- the intellectual development of pupils with the aim of ensuring their ability to continue their education.

This can be accomplished by providing for several steps or levels in the structure of natural science subject matter to correspond to the junior, intermediate and senior schoolchild.

The child's first acquaintance with natural phenomena, with the properties and structure of matter, and with the plant and animal world occurs in the context of nature studies in the primary school. Later on, in grades V-VIII, courses in geography, botany, zoology, physics and chemistry provide the schoolchild with an opportunity to master the more important concepts and laws in science, as well as to gain scientific insight into phenomena in accordance with his or her age-level and level of development (pressure in liquids and gases and an understanding of the nature of that pressure, conversion of mechanical energy into potential energy, the heating of bodies through heat transfer and the performance of mechanical work, Brownian motion, diffusion, the chemical combination of elements, chemical reactions, the scientific systematisation of the plant and animal kingdoms, etc.). This stage of familiarization with the elements of scientific theories and the scientific explanation of scientific phenomena is helpful in developing in the pupil the attitudes and aptitudes required for the study of the natural sciences on a theoretical basis.

The most radical change to have occured in secondary educational subject matter over the last few years is the raising of the level of theoretical generalizations based on fundamental theory within the regular school subjects.

*Whenever the word "Grade" is mentioned in the text the author is referring to a school year.

The contents of the school mathematics course have been reviewed to include elements of mathematical anaysis.

The curriculum has been shorn by a number of concepts not readily grasped by the schoolchild which have no fundamental significance as far as his or her mastery of the basic material is concerned. Greater attention is being devoted to the development of the capacity to think logically on the basis of theoretical constructs, proofs of theorems, and problem-solving. An improved system of exercises has been developed with a view to instilling practical abilities and skills in the use of newly acquired knowledge. A closer link between the contents of mathematics and physics courses has been established.

Considerable changes have been introduced, in the first-level physics course (grades VI-VII) with the phenomenology of a number of effects now being explained on the basis of fundamental notions concerning molecules, atoms and electrons. The second-level physics course (grades VIII-X) is structured on a consistently theoretical basis; it includes the mechanics of a material point, molecular physics with elements of thermodynamics, electrodynamics and certain added information drawn from the special theory of relativity and quantum physics.

The inorganic chemistry course is built up on the basis of theoretical concepts concerning the structure of atoms, elements, and their inorganic compounds, with the periodic law and periodic table of the elements devised by D. I. Mendeleev as the centerpiece.

The organic chemistry course is structured on the basis of the theory of the chemical structure and the notion that substances develop from relatively simple to the most complex forms involved in the vital activities of organisms.

The biology course is based on Darwin's principle of evolution, which is presented from the standpoint of cytology, genetics, ontogenesis, ecology and the systematic aspects of botany, zoology, and human anatomy and physiology.

It would be incorrect to interpret this raising of the level of theoretical generalizations as having been undertaken solely in order to bring educational subject matter into line with the achievements of modern science. In fact, the raising of the scientific level of general secondary school subjects was effected with the aim of dealing with a number of inter-related problems. In addition to those already mentioned, these include the following:-

- shaping a scientific world outlook;

- shaping the ability of pupils to think in theoretical terms and equipping them with the most powerful, the most rational, and the most economical means of acquiring knowledge, that is, scientific theory.

- equipping pupils with the theoretical background necessary to an understanding of the most important achievements of science, culture, engineering and technology, and the more important recent trends in scientific and technological development.

Structuring the contents of a school subject on the basis of scientific theory enables pupils to acquire a notion of the structure of scientific knowledge in the spirit of materialistic epistemology, i.e. to proceed from active contemplation to abstract thinking and from abstract thinking to practice.

As they master general subjects, pupils come to understand the role of facts in the construction of a hypothetical model of phenomena, in the genesis of scientific concepts and in the formulation of laws and principles constituting the basis of any theory. They gain a grasp of the heuristic power of theory, whereby consequences logically derived from theory enable one to predict the development of phenomena and to control them. At the same time the secondary school pupil acquires some insight into the limits of applicability of a theory.

The increasing role of science in the acceleration of scientific and technological advance in the development of the USSR national economy, as well as the increased demands being imposed in the field of personnel training and competence have determined the most important new trends in the theory and practice of polytechnical education. The chief of these are:-

- the reworking of subject matter to make it reflect the advances in science, engineering and technology underlying current progress in industry and agriculture;

- the transition in the system of school subjects from a consideration of individual examples of the practical application of science to the study of the most important trends in present-day scientific and technological progress;

- increased attention to the shaping of practical capabilities and skills through laboratory exercises, workshop activities, problem solving, as well as the fostering of creative faculties through optional and out-of-school assignments.

Thus, the new physics programme includes such general course material as mechanics and the mechanisation of production, the basic laws of electrodynamics and their technical application, the successes already achieved and the prospects of electrification in the USSR, the nation-wide development of communication, the successes and prospects of nuclear power generation in the USSR, and physics as it relates to the scientific and technological revolution.

The principal themes of the chemistry course are the relationships involved in chemical processes and the principles underlying our ability to control them. The course curriculum and textbooks set out the scientific fundamentals of such processes as fertilizer production, metallurgy, the processing of fossil fuels, organic synthesis, and the production of polymer materials.

The biology course takes up issues involved in the breeding of plants, animals, and microorganisms. Examples of the development of high-yield agricultural crops and domestic animal breeds are studied.

The theoretical fundamentals of the more important trends of scientific and technological progress help pupils to secure a better grasp of the key ideas which underlie the functioning of various modern machines, instruments, devices, processes, phenomena, and objects in use in the household, in industry, and in agriculture. The most important of these are included in the subject matter of general course curricula.

Every modern Soviet pupil taking physics courses studies the principle of operation of vacuum and semiconductor devices, lasers, elementary particle accelerators and nuclear reactors. He or she comes to understand the scientific fundamentals of the use of the processes of electrolysis, electrical discharges in a gas and in a vacuum, radio communications, spectral analysis, the photoelectric effect and nuclear reactions.

Chemistry courses provide pupils with knowledge about chemical kinetics and chemical equilibrium. This enables them to understand the nature of the factors which determine the rates of chemical reactions as well as to see how the equilibrium yield of the products of chemical reactions can be increased.

The embodiment of the polytechnical principle in the newly designed biology courses also makes the latter different from what they were in the past. Whereas previously the principles of biology were taught by citing examples of agricultural plants and animals and by describing certain techniques and measures employed in agriculture and in animal husbandry, the trend today is to stress the exposition of the theoretical fundamentals of agriculture, with particular emphasis on the ways of

increasing the productivity of the livestock and plant breeding industries and on issues involved in the rational use of natural resources and protection of the environment.

The revised school programmes differ from the previous ones in a number of fundamental ways. In particular, there is a new emphasis on the practical skills to be acquired by pupils as they go about studying a given subject. They are called upon to master the operation of various instruments, to make measurements and to treat experimental data, to cope with computational problems, to construct and read graphs, etc. Such a redefinition of the goals of instruction and learning generates a more responsible attitude to laboratory and other practical tasks as well as to practical work methods. There can be no doubt that this is an important trend which has as one of its consequences the strengthening of the function of laboratory and practical exercises within the context of general course work.

The most important new trends in the development of subject matter and teaching methods are decisive in setting new goals in teacher retraining, calling for:

- mastery of the conceptual basis of major theoretical generalizations embodied in school subjects and the ability to convey them to the pupil;

- mastery of the techniques of motivating pupils to study (imparting the feeling that possessing knowledge is a matter of prestige, that what is being studied and what the pupil is learning is related to real life, that practical skills are indispensable, etc.);

- gaining a proper understanding of the demands to be imposed on pupils as they go about securing theoretical knowledge and practical skills;

- mastery of the skills of classroom instruction and of the assessment of that instruction.

The task of raising teacher competence is facilitated by the revised programmes on each subject which constitute the basic document guiding the work of each teacher. These set out, among other things,

- the goals of training and education;

- the most important ways, means and methods of obtaining the necessary results;

- the principles of identifying what is primary and what is secondary within each subject area;

- the role of theory and experiment within each course;

- the significance of the demonstration type experiment and of laboratory exercises;

- ways and means of dealing with the issues of advanced technology in the light of applied science;

- relationship between subjects;

- requirements as regards knowledge and skill acquisition by pupils and evaluation standards;

- the basic literature to be studied.

What follows is a presentation of all of the major trends in the improvement of natural sciences and mathematics education with particular reference to the teaching of mathematics, physics, chemistry and biology.

1.0. MATHEMATICS

1.1. The contents of the mathematics course in Soviet schools

The restructuring of mathematics teaching in Soviet schools carried out in the 1970s meant first and foremost the modernization of the mathematics course for secondary schools to bring it into line with the present level of mathematical science. One of the requirements reflected in the patterning of the present day school programme in mathematics was that of imparting the necessary unity to the subject matter. The evolution of this requirement set in motion a trend towards the gradual unification of the various subjects covered within the school mathematics course.

Prior to the transition to the new course content, the mathematics course in Soviet schools consisted of four subjects – arithmatic, algebra, geometry, and trigonometry, with all three subjects being taught in parallel at certain stages: arithmetic, algebra and geometry in grade VI, and algebra, geometry and trigonometry in grades IX-X. Gradually, however, mathematicians and methodologists came to think that such a subdivision of the subject matter was unreasonable. Scientists became convinced that the teaching of arithmetic and trigonometry in isolation from one another not only failed to match the position occupied by these disciplines within the system of mathematical sciences as a whole, but that it did not in fact justify the methodological difficulties entailed by their breakdown into separate subjects. The first subject to be eliminated as an independent entity was trigonometry. The subject matter of this course was accordingly split up between algebra and geometry. The next subject to go was arithmetic. At the present time pupils in the first five years (grades I-V) study a subject called not 'arithmetic' but rather 'mathematics', which includes units of an arithmetic and algebraic character as well as elements of geometry.

School mathematics in grades VI-VIII consists of two subjects, algebra and geometry, which pupils study in tandem but using different textbooks. The introduction into new mathematics programmes of modern generalizing concepts has provided an opportunity for the implementation of a unified approach to many of the issues dealt with in algebra and geometry courses, making it possible to overcome their traditional separation into two distinct subjects and leading to the establishment of a close interrelation and interpenetration of the formerly separate courses. For example, the consistent application of the method of coordinates is something which is favourable to the interpenetration of algebra and geometry courses, inasmuch as the coordinate method makes it possible to represent algebraic relations as relations between geometric objects and vice versa, i.e. to move from algebraic terminology to its geometric equivalents and back.

The use of vectors in the school geometry course enables the teacher to present geometric material using the tools of algebra and therefore serves the purpose of bringing two formerly separate school level mathematics courses closer together.

The injection of elements of mathematical logic has provided groundwork for employing a single, general language in presenting algebra and geometry course units.

The school mathematics course for grades IX-X likewise consists of two subjects, namely algebra and the beginnings of analysis and geometry.

A salient feature of the new school course in mathematics is that it constitutes a unified system structured on the basis of several methodological principles, the most important of which are as follows:

1) The grouping of all material around a compact system of pivotal (basic) concepts.

2) The gradual increase of the role of the deductive method.

3) The gradual and consistent establishment and maintenance of intrasubject and intersubject links.

4) An increased role assigned to exercises.

There is a gradual intensification of the role played by the deductive method as the pupil moves from one grade to the next. Inductive presentation of course material predominates in grades IV-V, where specific examples are used to explain the meaning of concepts, laws and facts. Thus, it is on the basis of specific examples that pupils in grades IV formulate the criteria of divisibility by 2, by 3, by 5, by 9 and by 10. It is by induction, on the basis of generalizations drawn from the pupils' everyday experiences, that children in grade V formulate the criterion of parallelism of straight lines. The application of this criterion to justify the device of constructing parallel straight lines and the justification of the parallelism of the opposite sides of a square and rectangle, on the other hand are presented deductively.

In studying the first specific functions in grades VI, pupils learn to construct the graphs of functions point by point, after which they are asked to investigate the properties of the function being investigaged. It is later, in studying the functions $y = ax^2$ and $y = ax^3$, that pupils begin to deal with the elements of a proof. Later on, after the pupils have seen from specific examples that the graph of the function $y = ax^2$ is symmetric with respect to the oy-axis, this fact is proved in its general form. Subsequently, the construction of the graph of a function is preceded by a simple analytical investigation (as, for example; in studying the function $y = \sqrt{x}$). When the function $y = \log x$ is taken up, all of the properties of this function are investigated analyticaly, the graph of this function being constructed by applying the property of graphs of mutually inverse functions.

In grades IX-X, reliance is placed largely on the deductive method, even though induction continues to be applied in a number of instances (as, for example, in the initial presentation of the notion of a derivative, and of the method of coordinates).

The consistant and purposeful maintenance of intrasubject and intersubject links finds its expression in the timely introduction of new notions and in the formation of the mathematical apparatus required for the study not only of mathematics itself, but of other subjects as well. This makes it possible to deal with appropriate study units on a sufficiently high theoretical level, systematically demonstrating the application of mathematical methods for the benefit of the pupil. The maintenance of intrasubject links between mathematics subjects in the course of instruction fosters a deeper and more conscientious assimilation of study material, favouring the elimination of formalism from the subject matter acquired, fostering the development of creative thinking, and helping to avoid unnecessary duplication in the presentation of various points.

The new mathematics programme provides for early familiarization with functional relationships, the use of letter symbols, the establishment of the ability to carry out the simplest identity transformations and to solve text problems using linear equations in a single variable. Abstracting himself from specific physical phenomena, the mathematics pupil learns to approach functions as abstract mathematical entities. The knowledge he has acquired in physics courses are used to investigate specific relations between the properties of the objects around him in terms of the appropriate quantities. For example, functions expressed by the formulae $y = kx + b$ and $y = kx$ have a differing physical interpretation if the variables y and x are taken to stand for particular quantities: they can express the dependence of distance travelled on time with uniform motion, the dependence of velocity on time with uniformly accelerating motion, the amount of heat released during complete combustion of a fuel on the fuel mass, the temperature in the depths of the earth on distance from the earth's surface, etc. In grade VIII kinematics is taught with the aid of the properties of a linear and a quadratic function. Understanding of the trigonometric function is made more secure by dealing with problems in statics and by presenting the concept of work. Mathematics and physics studies in grades IX and X find good support in pupils' use of the elements of mathematical analysis in the study of physics. Thus, the derivative is employed when taking up some of the issues in electrodynamics in grades IX.

The more extensive use of exercises finds its expression in the active employment of exercises at all stages of concept formation, in the study of mathematical language, in the acquisition of problem solving methods and devices, etc. The theoretical material and the system of exercises in the present-day mathematics textbooks are organically interrelated and complementary. The theoretical material is broken down into small units, each such unit accompanied by a set of exercises. Such an arrangement of the textbook material makes it possible to ensure conscientious and active learning.

A further new element in the current mathematics teaching methodology is the clear definition of the results of study which are to be achieved by mastering each individual section, paragraph, topic, and the course as a whole by means of a carefully thought out system of exercises. Previously this matter was dealt with by teachers on an intuitive basis, whereas today most textbooks and teachers' guides as well as other learning aids embodying systems of exercises selected precisely with this consideration in mind.

Another characteristic of the school mathematics course is that it provides for the acquisition of abilities and skills on the basis of quite simple exercises. Excessively complicated and cumbersome exercises have been excluded from non-optional sets. The need to keep to this requirement was due mainly the desire to augment the general educational role of the mathematics course. The earlier mathematics programmes and textbooks provided similar means for the acquisition of all required material , i.e. for a uniform mastery of all textbooks contents such as definitions and theorem proofs. The present mathematics textbooks, on the other hand, highlight those concepts definitions which the pupil is expected to be able to reproduce. The approach to theorems is similar: a certain number of theorems which the pupil is expected to be able to prove are highlighted in the text.

It must be noted that modern textbooks likewise contain supplementary reading material such as historical background and extra, more difficult problems. These are intended to heighten pupil interest and to encourage the more avid of the young mathematicians. The new mathematics textbooks likewise contain an abundance of drawings, diagrams and other illustrations. The approach taken to illustrating the new study material is a qualitatively new one. Diagrams and drawings are being made to play a more important role in concept formation than in the past. Much more room is being given to relatively simple and easy-to-understand models that allow the pupil to grasp the salient aspects of concepts presented. For example, the introduction and use of the coordinate line and coordinate plane starting in grade V makes it possible to represent algebraic relationships via geometric images and is thus very helpful in helping the pupil to understand any number of points: inequalities, operations on positive and negative numbers, the notion of the modulus (absolute value) of a number and the solution of equations and systems of equations.

The changeover to the new mathematics curriculum has brought about significant changes in the process of learning mathematics. The most striking feature of this process are:

1) The activation of the pupil's cognitive activity at all stages of learning.

2) The consistent and purposeful training of the pupil in the assimilation of new material to ensure the accessibility of the course material to all pupils.

3) A systematic effort to develop creative thinking through a highly explicit presentation of the logical structure of the course, i.e. a clearcut demonstration of the links and relationships between the concepts.

The mathematics course holds an important place in the overall general secondary school curriculum. Mathematics class-work takes up six hours a week in grades I- III, six hours a week in grades IV-VIII, five hours a week in grade IX and four and a half hours a week in grade X.

TABLE 1

Subject	I	II	III	IV	V	VI	VII	VIII	IX	X
	No. of hours per week									
Mathematics	6	6	6							
Mathematics (arithmetic, the elements of algebra and geometry)				6	6					
Algebra						4	3/4*	4		
Algebra and the elements of analysis									3	3/2*
Geometry						2	3/2	2	2	2
TOTAL				6	6	6	6	6	5	4,5

*The numerator indicates the number of hours per week during the first semester, the denominator the number of hours per week during the second semester.

The new mathematics programme incorporates a considerable body of stable material, i.e. the development of the notion of a number, identity transformations of numerical expressions and expressions containing variables, the theory of equations, the theory of functions (the selection of functions studied largely corresponds to the classical assortment), and a systematic course in geometry.

In the preparation of the new mathematics course contents considerable emphasis was placed on assessing the value of the traditional material and the traditional approaches to its study, as well as to the exclusion of issues and points of no general educational educational and/or practical significance.

The new programme provides for familiarization with the notions of algebra and the elements of geometry beginning in grade IV rather than in grade VI as was the case traditionally. The result has been an advance of a year or of a year and a half in the introduction of formulae and equations, percentage, positive and negative numbers, coordinates and graphs, the notion of a function and certain individual types of functions (pupils have received their first information concerning exponential, logarithmic and trigonometric functions by the time they complete grade VIII). The rational distribution of subject matter over various grade levels and the elimination of material of no great general educational value have made it possible to devote more time in the higher grades to the study of material important to the general education of the young person such as the notions of a derivative and an integral, the rudiments of linear programming, the basics of computer operation and the role of computers in the national economy.

Over the past few years Soviet educators have completed work on the improved and streamlined mathematics programme which has now been issued in the form of an explanatory note and three sections entitled: "Requirements for the mathematical training of pupils", "Subject matter" and "Layout of the study material by topics". The first section specifies mandatory levels of achievement within the overall mathematics course, while the second stipulates the stable minimum volume of material which must be covered in the school programme.

The material to be studied within each group of grades (I-III, IV-V, VI-VIII, IX-X) is subdivided along "contents lines" bringing together closely interrelated course topics.

The goal of the mathematics course in grades I-III consists of familiarizing the pupil with arithmetical operations on the natural numbers and the application of these operations to the simplest quantities. Another aim is the provision of a groundwork for understanding simple geometric figures and their properties. As they proceed with their studies, pupils learn to carry out arithmetical operations on natural numbers to measure elementary quantities and to subject them to the appropriate operations, as well as to be able to recognize and draw the simplest gemetric figures.

Table two is a list of the principal material covered in the mathematics course in grades I -III.

TABLE 2

Grade	Subject Matter
1 - 111 (612 hours)	<u>Elements of Arithmetic</u> Reading and writing of integers up to a million. The number 0. Comparison of numbers. Arithmetical operations on natural numbers. The properties of operations. Finding the unknown component of an operation. The order of operations in an expression. Parenthesis, brackets, braces. Fractions and decimals. Reading and writing of fractions. Finding the fraction of a number. Examples of quantities: length, area, time, mass, cost. The units (dimensions) used to express these quantities. Examples of relationships between quantities (path length, velocity and time; area and the lengths of the sides of a rectangle, etc.) Solution of arithmetic problems given in the text. <u>Elements of geometry</u> Recognition of geometrical figures (lines, sigments, rectangles, circles) with surrounding objects and models as illustrations. Drawing and construction of figures on paper. Cutting up of figures and making new figures. Measurement of segments. Measurement and calculation of the area of a rectangle.

The mathematics course for grades IV-V includes arithmetic, algebraic and geometrical material (with a reduced amount of arithmetic as compared with the past curriculum). The goals of the course include the use of new material to generalize and develop the mathematical knowledge, skills and devices mastered in primary school as well as preliminary instruction to prepare the pupil for the systematic algebra and geometry to come. In studying mathematics in grades IV-V, pupils learn to calculate using natural and whole numbers and ordinary and decimal fractions. They assimilate notions concerning the use of letter symbols to express the properties of numbers and learn to construct and solve simple linear equations in accordance with the conditions of a problem. They likewise continue to develop their insights into geometric concepts, learning to recognize and construct more complicated geometric figures and to measure geometric quantities.

One of the most important aims of mathematics training in grades IV-V is the development in the pupil of a secure grasp of operations on whole numbers and decimals. The ability to calculate using natural, positive and negative numbers and decimal fractions is considered to be of great practical significance.

The study of geometry in grades IV-V is of a preparatory type, which means that the pupils are not asked to assimilate systematized information concerning abstract geometric figures, but continue to work with their real prototypes. Special attention in these classes is devoted to the presentation of the most important notions of geometry (a geometric figure, segment, straight line, radius, angle, the bisector of an angle, adjacent angles, parallel straight lines, a perpendicular straight line) as well as to the development of geometric construction skills. The pupils learn to use a compass, ruler, triangle and protractor to construct parallel and perpendicular straight lines and triangles in accordance with set elements of the figure.

A list of the principal subject matter of the mathematics course for grades IV-V is presented in Table 3.

TABLE 3

Grade	Subject matter
	<u>Elements of arithmetic</u>
IV-V (408 hours)	Natural numbers and zero. Reading and writing of natural numbers. Arithmetic operations on natural numbers and properties of arithmetic operations. Simple and compound numbers. Decomposition of a natural number into simple factors. The least common multiple and largest common denominator. Criteria of divisibility by 2, 3, 5, 9, 10. Division with a remainder. Ordinary fractions. Proper and improper fractions. The principal property of a fraction. Arithmetic operations on ordinary fractions. The arithmetic mean. Proportions. The principal property of proportions. Solving problems with the aid of proportions. Decimal fractions. Arithmetic operations on decimal fractions. Rounding off. Percentage. Simple percentage problems. Positive and negative numbers.

Opposite numbers and the modulus (absolute value) of a number. Comparison of numbers. The rules of arithmetic operations on positive and negative numbers. Whole and rational numbers. The integer and fractional parts of a number. Arithmetic operations on rational numbers and the properties of such operations. Numerical expressions. The square and cube of a number.

Elements of algebra

The use of letters in writing out expressions. The numerical value of a letter expression and its calculations with the aid of formulae. The expression in letters of the properties of arithmetic operations. The elementary transformations of expressions: removal of and inclusion in parenthesis, carrying of the common factor outside the parentheses, cancellation of similar terms. Construction and solution of linear equations.

Elements of geometry

Geometric figures: the segment, straight line, radius, angle, triangle, square, rectangle, circle, and disc. The notion of the equivalence of figures. Examples of symmetric figures.
The cube, rectangle parallelepiped and sphere. Examples of quantities: length, area, volume and angle in degrees. The units of measurements of length area, volume and angles. Scale. The area of a rectangle. The area of a right triangle. The volume of a rectangular parallelepiped. The formulae for the circumferance and area of a circle. The ruler, triangle; protractor and compass. Construction of segments and of segments and angles of specified magnitude. Construction of a perpendicular to a staight line. Construction of parallel and straight lines.
Representation of numbers along a straight line. The coordinate of a point on a straight line; finding the distance between two points with given coordinates. The rectangular coordinate system on a plane; the abscissa and ordinate of a point. Examples of graphs.

The problems set in the algebra course for grades VI-VII relate to the sytematic study of the elements of algebra and elementary functions on the basis of the pupil's ability to compute as developed at lower grade levels and intended to serve as the necessary groundwork for the study of related subjects as well as for the algebra and basic calculus to come in grades IX-X. The course is designed to equip the pupil for generalizing and systematizing knowledge concerning real numbers and to develop and build up confidence in computing ability. Other goals pursued at this level include mastery of the skills of carrying out identity transformations of the basic types of algebraic expressions (polynomials, algebraic factors, powers and roots); of the methods of solving algebraic equations and first- and second- order inequalities, as well as equations and systems reducible to these equations and systems; of the simplest functions and their properties.

A list of the principal subject matter of the algebra course for grades VI-VIII is given in Table 4.

TABLE 4

Grade	Subject matter
VI-VIII (391 hours)	<u>Rational and Irrational numbers</u> Rational numbers. The representation of rational numbers in terms of infinite periodic fractions. The notion of a rational number. The number line. The square root. The arithmetic square root and its properties. Approximating the square root. The table of squares and square roots. Numerical inequalities and their properties. The term-by-term addition and multiplication of numerical inequalities; the approximate value of a number. Absolute and relative errors. Arithmetic operations on the approximate values of quantities. Familiarization with the use of an electronic calculator. The binary system. General information about computers and programming. Decimal logarithms and their properties. Elementary calculations with the aid of a slide rule. <u>Identity transformations</u> The polynomial. The standard form of a polynomial. The degree of a polynomial. The conversion of the sum, difference and product of polynomials into a polynomial of standard form. The factoring of polynomials. The formulae: $(a \pm b)^2 = a^2 \pm 2ab + b^2$; $a^2 - b^2 = (a-b)(a+b)$; $a^3 + b^3 = (a+b)(a^2 - ab + b^2)$; $a^3 - b^3 = (a-b)(a^2 + ab + b^2)$. The use of reduced multiplication formulae in the transformation of expressions. Algerbraic fractions. The principal property of a fraction and the reduction of fractions. The sum, difference, product and quotient of fractions. A power with a natural exponent and its properties. A power with a whole exponent and its properties. The n-th degree root and its properties. A power with a rational exponent and its properties. Arithmetic and geometric series, formulae for the n-th term and the sum of the first n terms of a series. <u>Equations and inequalities</u> The equation. The roots of an equation. Linear equations with a single unknown. The quadratic equation (the formula for roots and the investigation of a quadratic equation). Viet's formulae. The quadratic trinomial. The factoring of a quadratic trinomial. The solution of elementary rational equations. Linear equations in two unknowns. The equation of a straight line on a plane. Systems of equations.

The solution of a system of two linear equations with two unknowns and its geometric interpretation. The solution of very simple systems containing a second-degree equation.
Linear inequalities with a single unknown.
Number intervals. The system of linear inequalities with a single unknown and its solution.
A second degree inequality with a single unknown. The solution of problems by the method of composite equations and systems of equations.

Elementary functions

The notion of a numerical function. Ways of specifying a function (formula, table, graph). The range and domain of a function. Increasing and decreasing functions. Even and odd functions.

The functions $y = kx$; $y = k/x$; $y = kx + b$; $y = x^2$; $y = \sqrt{x}$; $y = \sqrt[n]{x}$ (where n is a natural number) and $y = ax^2 + bx + c$; their properties and graphs. Very simple graph transformations.

Algebra lessons in grades VI-VII require pupils to gain a grasp of the specification of real numbers by means of periodic and non-periodic fractions. Other topics covered are the basic algorithms of identity transformations (the removal of parentheses and inclusion in parentheses, cancellation of similar terms, the addition, subtraction and multiplication of polynomials, the use of reduced multiplication formulae, arithmetic operations on algebraic functions in the simpler cases, the transformation of powers and roots); algorithms for solving the basic types of equations, inequalities and systems; the reduction of more complex equations and inequalities of the basic types; the investigation of functions and the construction of their graphs by elementary methods on the basis of a relatively few function types (direct and inverse proportions, linear and quadratic functions, and the functions $y = x^n$ and $y = \sqrt[n]{x}$ with a natural n). The pupils likewise develop the ability to express relationships between quantities in the form of functions and become skilled in applying various ways of specifying functions, going from one form to another (calculating the value of a function given by a formula, reading of graphs etc).

The aims of the geometry course for grades VI-VIII include the systematic study of the basic facts of plane geometry and its methods on the basis of the knowledge about geometry assimilated at earlier grade levels and with a view to providing the necessary groundwork for studying related topics, including solid geometry in grades IX-X. As they go about mastering the course material, the pupils build up a store of systematic knowledge concerning the basic figures on a plane and their properties; about the similarity and congruence of figures and the basic types of geometric transformations and their use in geometry; about geometric constructions common in graphic work. They likewise acquire skills in the measurement and calculation of lengths, angles and areas as required in the solution of various geometric and practical problems. Finally they become familiar with the use of the analytical apparatus (algebraic transformations and equations and the elements of trigonometry, analytical geometry and vector algebra) for solving problems in geometry.

A list of the principal matter of the geometry course for grades VI-VIII is presented as Table 5.

TABLE 5

Grade	Subject matter
VI-VIII (221 hours)	**Gemetric figures and their properties** The basic notions of plane geometry. The geometric figure. concept of the axiom and the theorem. Intersecting and parallel lines. The criteria for straight lines being parallel. Perpendicular straight lines. Therems cncerning perpendicular lines. The triangle. The properties of the equilateral triangle. The sum of the angles of a triangle. The properties of the midline of a triangle. The theorem of Pythagoras. The parallelogram and its properties. The characteristics of a parallelogram. The rectangle, rhombus, square and their properties. The trapezoid. The polygon. Regular polygons. The circle and the disk. The tangent to a circle and its properties. The properties of the central perpendicular; a circle described about a triangle; the properties of a bisector of an angle: a circle inscribed in a triangle **Equality and congruence of figures** **Gemetric transformations.** The notion of the equality of figures. The criteria of equality of triangles. The notion of the congruence of figures. The criteria of the congruence of triangles. Axial and central symmetry; rotation and parallel transposition. Examples of figures exhibiting symmetry. **Measurements and constructions** The length of a segment, the distance betwen two points. The basic properties of distances and the inequality of triangles. The distance between a point and a straight line. The properties of the magnitudes of angles. The angular magnitude of a circular arc. Circumference and arc length. The concept of area and the basic properties of area. The areas of a rectangle, triangle, parallelogram and trapezoid. The ratio of the areas of congruent figures. The areas of a circle and parts of a circle. Simple problems in constructing figures using a compass and ruler. Problems involving the calculation of unknown lengths, angles and areas.

Basic trigonometry

The sine, cosine and tangent of an angle. The identities

$$\tan\alpha = \frac{\sin\alpha}{\cos\alpha}; \qquad \text{and } \sin^2\alpha + \cos^2\alpha = 1.$$

The reduction formulae

$\sin(90^\circ - \alpha) = \cos\alpha$; $\sin(180^\circ - \alpha) = \sin\alpha$;

$\cos(90^\circ - \alpha) = \sin\alpha$; $\cos(180^\circ - \alpha) = -\cos\alpha$

The values of the sine, cosine and tangent of the angles 0°, 30°, 45°, 60°, 90°, 180°. Trigonometric function tables.
Relationships between the sines and angles of a right triangle.
Sine and cosine theorems. Resolution of triangles.
The use of trigonometry for solving problems in geometry.

Coordinates, Vectors.

Rectangular coordinates on a plane. The formulae for the distance between two points with specified coordinates lying in a plane. The equations of a straight line and a circle.
The vector; the length and sense of a vector. Vector addition and its properties. Multiplication of a vector by a scalar and its properties. Colinear vectors. The coordinates of a vector. The scalar multiplication of vectors and its properties. The angle between two vectors.
The use of coordinates and vectors in proving theorems and solving problems.

Geometry pupils in grades VI-VIII develop the ability to draw inferences from statements concerning the equality and congruence of figures; to construct (using reasoning of the proof type) a figure which a given figure becomes under a given type of geometric transformation; to find equal (congruent) triangles in specific instances (not requiring artificial additional constructions) and the ability to prove their equality (congruence) on the basis of the corresponding criteria or of the properties of geometric transformations. They also acquire skills in applying the already familiar analytical apparatus to cope with standard exercises whose solution can be arrived at with the aid of a given algorithm (graphic addition and subtraction of vectors, resolution of triangles, the use of scalar multiplications to calculate the length of a vector and the angle between vectors, etc.), as well as simple practical problems which can be reduced to standard problem (ground measurements, resolution of forces, etc).

The purpose of the course in algebra and basic analysis consists in rounding off the various topics in algebra begun in the eight-year school and in familiarizing the pupil with the rudiments of analysis (basic differential equations and integral calculatus) as a tool for the study of functions and the solution of problems in geometry, physics and applied mathematics. Because some pupils finish their secondary education upon completing grade VIII, the course is designed to provide for the generalization and systematization of knowledge, securing the knowledge and skills acquired by the pupils in the course of their study of algebra throughout the eight-year school and developed through purposeful repetition and review. As they work through the course, the pupils build up their familiarity with functions by coming to understand power, exponential logarithmic and trigonometric functions. They are given an opportunity to systematize and complement their understanding of the basic functions and their properties, and learn to deal with the identity transformation of exponential, logarithmic and trigonometric expressions and to use these transformations in solving problems. Finally, they become familiar with the basic concepts, results and methods of mathematical analysis at a level enabling them to investigate elementary functions and to solve easy problems in geometry, physics and applied mathematics as well as to cope with relatively simple transcendental equations and inequalities and systems of inequalities constructed on the basis of functions already studied. A list of the principal subject matter of the course in algebra and basic analysis in grades IX-X is presented in Table 6.

TABLE 6

Grade	Subject Matter
IX-X (187 hours)	<u>Complex numbers*</u> The concept of complex numbers. Arithmetic operations on complex numbers. The geometric interpretation of complex numbers. The trigonometric form of a complex number. Multiplication and division of complex numbers in trigonometric form. Solution of quadratic equations. The Fundamental Theory of Algebra. <u>Elementary functions</u> Power, exponential and logarithmic functions, their properties and graphs. Natural logarithms. The notion of inverse functions. Radian measure. Trigonometric functions of a numerical argument: sine, cosine, tangent, cotangent. The periodicity of functions. Properties and graphs of trigonometric functions. Inverse trigonometric functions. Arcsine, arccosine, arctangent.

*The inclusion of a unit on 'Complex numbers' is tentative. As text-books are revised, it will be included as a required subject provided the necessary number of hours are available.

Identity transformations

Basic exonential and logarithmic identities.

$$a^x \cdot a^y = a^{x+y} \quad (a^x)^y = a^{xy}$$

$$\log_a xy = \log_a x + \log_a y$$

$$\log_a \frac{x}{y} = \log_a x - \log_a y;$$

$$\log_a x^p = p \log_a x; \quad \log_a x = \frac{\log e^x}{\log e^a}$$

and their use for the transformation of expressions. Trigonometric formulae for: (a) reduction; (b) the relationship between trigonometric functions of a single arguement; (c) addition and subtraction; (d) a double and a halved argument; (e) the sum and difference of the same trigonometric functions of the same argument or different arguments. The use of trigonometric formulae in the transformation of expressions.

Equations, inequalities, systems

Solution of rational equations and inequality. The method of intervals. The simplest irrational, exponential, logarithmic and trigonometric equations and inequalities. The solution of equations and inequalities reducible to simplest form.
The solution of systems and inequalities. The notion of the equivalence of equations, inequalities and systems of equations and inequalities.

Derivatives and their applications

The derivative. The geometric and mechanical meaning of the derivative. The tangent to the graph of a function. Derivatives of a sum, a product, and a quotient. The table of derivatives of elementary functions. The criteria of increase and decrease of a function. The use of a derivative to find the maximum of a function. Construction of function graphs and solution of maximum-minimum problems using derivatives.

Integrals and their applications

The indefinite integral. The table of integrals of elementary (power, exponential, sine, cosine) functions. The simplest cases of determining the indefinite integral.
The area of a curvilinear trapezoid. The definite integal as the limit of integral sums. The Newton-Leibniz formulae. The use of integrals for solving elementary problems in geometry and physics. Examples of differential equations.

As may be seen from the above table, the course in algebra and basic analysis contains a major traditional component, namely systems of equations, trigonometric equations and identities, and logarithmic and exponential equations. However, their role in the overall school curriculum has been radically altered. The school programme no longer calls for the solution of complex logarithmic and exponential equations and inequalities. When it comes to trigonometric equations, the simplest of these are complemented by a consideration largely of those equations which are reducible to quadratic equations in terms of sines, cosines and tangents. Very simple homogeneous equations are likewise considered. The identity transformations carried out in proving trigonometric identities and in solving equations, inequalities and systems of equations and inequalities are likewise quite simple due to the simplification of expressions.

The principal purpose of studying derivatives, integrals and elementary differential equations is to provide the pupil with basic knowledge concerning these very powerful mathematical tools. Thus, for example, in the presentation of the definite integral, emphasis is placed on its geometric meaning and its use in the computation of areas and volumes of geometric figures.

The goals pursued within the geometry course at the level of grades IX-X are the systematic mastery of the elements of solid geometry required for solving problems commonly occurring in practice, as well as the provision for a deeper and more secure grasp of subject matter already taken up in previous grades. Inasmuch as the grades in question constitute the final phase of secondary school education, much attention is given to the securing of basic skills and to the systematization of acquired knowledge in the case of both fresh and revision material. As they proceed through the course, pupils obtain systematic knowledge concerning the principal forms of solid figures

and their properties. They also learn to apply the course theorems for solving problems involving the representation of three dimensional figures on a plane and the determination of their various properties (angles, lengths, areas and volumes); finally, they become acquainted with the analytical methods of dealing with problems in solid geometry.

A list of the principal subject matter of the geometry course for grades IX-X is presented as table 7.

TABLE 7

Grade	Subject Matter
IX-X (136 hours)	Geometric figures and their properties
	The basic concepts of solid geometry. The axioms of solid geometry. The relative position of two stright lines in space (intersecting, parallel and crossed straight lines). The relative position of a straight line and a plane; intersecting and parallel straight lines and planes. The criterion of parallelism of a straight line and a plane. The perpendicularity of a straight line and a plane. Theorems on the parallelism and perpendicularity of a straight line and a plane. The relative position of two planes; intersecting and parallel planes. The criterion of parallelism of two planes. The perpendicularity of two planes. Therems on the parallelism and perpendicularity of planes. Dihedral angles. Polyhedra: the prism and the pyramid. Right and regular prisms, the regular pyramid. The parallelepiped and its properties. The notion of regular polyhedra. The cylinder and the cone. The sections of a cylinder and a cone by planes passing through their axis or by perpendicular planes. The notion of bodies and surfaces of rotation. The ball, and the sphere. The plane tangent to a sphere. Symmetry with respect to a point and to a plane. Examples of bodies and surfaces having symmetry. Parallel translation. The notion of the equality and congruence of figures.
	Measurements and constructions
	The angle betwen straight lines and the angle between a straight line and a plane. The line angle of a dihedral angle. The notion of volume and the basic properties of volume. The volumes of polyhedra (rectangular parallelepiped, prism and pyramid). The volumes of bodies of rotation (cylinder, cone, sphere). The areas of the lateral and complete surfaces of a cylinder and a cone. The surface areas of a sphere. Parallel projection and its properties. The representation of figures on a plane. The area of the projection of a polyhedron. Constructions in three dimensions.

Coordinates, Vectors

The orthogonal coordinate system in space. The formula for the distance between two points in space with specified coordinates. The equation of a plane and of a sphere. Vectors in space. Vector addition and its properties: multiplication of a vector by a scalar and its properties. The coordinates of a vector. Scalar multiplication of vectors and its properties. The angle between vectors.

Pupils in grades IX-X develop the ability to represent three-dimensional figures on a plane relying on the properties of parallel projection. They are required to visualize (with the aid of models, drawings and their imagination) the relative disposition of solid figures, using their perception of that relative position to seek out ways of solving a given problem and of interpreting the results obtained.

The inclusion of elements of analysis in the school mathematics course enables pupils in grade X to derive formulae for calculating the surface areas and volumes of certain solids using the notion of the derivative and the integral.

1.2. The development of a scientific way of thinking through the study of mathematics

The raising of the scientific level of the school mathematics course and the methodological principles constituting the basis of the new programmes and textbooks have created new opportunities for the development and enrichment of the educational aspects of the course and for the shaping of a scientific way of thinking among pupils.

At the present stage of progress in science and technology a knowledge of the fundamentals of mathematics and the understanding of its role and place in a system of interrelated sciences is becoming an integral part of general culture. This in turn requires increased attention to those aspects of mathematics teaching which have to do with the development of an appropriate world view. The principal orientations in the inculcation of a scientific world outlook in the process of mathematics teaching are determined by the specifics of the subject itself and consist in the demonstration of the links between mathematics and reality and by the need to develop a proper understanding of the role of abstraction and logic in learning about the world around us. The pupil must also come to understand the role of practice in the development of mathematics and of the significance of applying the results of mathematical thought.

One of the more important prerequisites for effective work aimed at the development of an appropriate world view in pupils is an organic link between educational considerations on the one hand and course content on the other. By making sure that pupils come to realize early in their studies that mathematics is concerned with the investigation of the general properties of objects and phenomena in the surrounding world, that it operates not on objects themselves, but rather on abstract concepts, it is possible to make the young person understand that mathematics does not destroy links with reality, but that quite the contrary it makes it possible to investigate that reality more deeply by drawing generalized theoretical conclusions which are widely applicable in practice.

The exposition of the links between mathematical notions and reality is handled differently at different levels. Thus, in grades IV-V the most important facts of mathematics are presented together with appropriate illustrations from real life. Virtually all of the "real world" which surrounds the pupil at home, in the street, in school, the world both near and far, including outer space, is reflected in the "stories" in which problems, examples and illustrations are couched. This creates a sound basis for the correct understanding of the nature of mathematical notions on the part of the pupil.

It is already at these grade levels that the essence of mathematical notions asabstractions of reality reflecting its general and essential propreties is presented to pupils by demonstrating the interrelations between the mathematical notions of a "triangle", "circle", "sphere" etc. and their material prototypes. The common basis of mathematical concepts and methods is demonstrated by way of text problems of differing content whose solution involves the construction of expressions or equations of similar form.

The presentation of mathematical knowledge within each section of textbooks for grades IV-V begins with classroom exercises allowing for the pupil's personal experience. For example, the presentation of the topic entitled "Writing out fractions" begins with a demonstration (drawings) of the cutting up of a cake. Having introduced the method of expressing fractional numbers, the authors of the textbook involves the pupil in solving problems calling for the "division of a path into its segments", "slicing a loaf of bread", "dividing the side of a square", "cutting a length of cloth into several parts", "paving a road", "using sugar to make jam", "sawing up a large board into smaller planks" and many others. The presentation of the theoretical material and the system of set problems ensure an appropriate progression in the grasp of mathematical concepts and the development of object-oriented thinking.

In presenting basic mathematical concepts, one must make sure that the pupil develops an understanding of the need to introduce such concepts and of the way that concepts can be used. To this end it is necessary to implement a methodology whereby the consideration of meaningful problems precedes the formulation of a given concept and any subsequent work on its logical structure and applications. Such an approach helps pupils realize that the new notion being introduced constitutes a generalization of the facts of real existance.

For example, one cannot and must not loose sight of the need to lay a proper groundwork for the grasp of such a widely used concept as the derivative. The need for its introduction is illustrated by way of examples readily understandable by the pupil such as the physical problem of the instantaneous velocity of motion and the geometric problem of constructing the tangent to the graph of a function. The shaping of the notion of a differential equation must also be based on facts known to the pupil.

In familiarizing pupils in grade X with the differential equations of harmonic oscillations it is necessary to show that the essence of the differential equations lies in interrelating the basic physical quantities expressed in mathematical forms. This means that the extensive applicability of such equations can be demonstrated through the proper choice of practical illustrations. The study of the equation of oscillations is best accompanied by a consideration of physical examples such as the oscillation of a load, the oscillation of a capacitor charge, etc, with emphasis upon the fact that changes in the state of a physical object with time proceed in accordance with a single law even though the forces which produce these changes are of differing physical character. By thinking about such simple examples pupils come to see that differential equations are a language in which nature has "recorded" its laws.

Mathematics is one of the principal disciplines to have determined the evolution and accelerated development of science and technology. For this reason science places primary emphasis on the development of mathematical theory and on improving its effectiveness when applied to practical ends. Dealing with this problem requires that due emphasis in mathematics studies be placed on the exposition of mathematical ideas, concepts and methods together with their applications to real-life situations.

Thus, in solving problems by approximate methods and in the approximation of integrals, pupils become acquainted with the basics of the theory of computational mathematics. These examples convince them of the usefulness of numerical methods and of the fact that the theory of computational methods is a highly ramified science with applications in situations involving quantitative laws expressible numerically. Such laws are dealt with in many disciplines (e.g. mathematics, physics, mechanics, economics, control theory, etc.). It may also be noted that mathematical methods are today being applied in the social sciences and humanities, with the mathematization of all the sciences already well under way. Each of the areas in which mathematics is applied entails specific problems whose solution requires a choice of the most effective mathematical method or methods. "The effectiveness of a method of computation is determined by the speed of computation which it affords and the quality or precision of the results it yields."

As one goes about shaping a scientific approach to thinking, it is very important that the pupil be made to see that applying mathematics to the solution of problems is a step-by-step process. The use of mathematics for the solution of any problem breaks down naturally into three stages. The first of these consists in pasing from the situation which must be dealt with to the formal mathematical model of the situation i.e. to a clearly stated mathematical problem. This is the stage of formalization. The solution of the mathematical problem thus formulated by the methods developed in mathematics for solving problems of the type under consideration constitutes the second stage i.e. that of solving the given problem within the given mathematical model. The third stage is that of interpreting the

resulting solution of the mathematical problem and the application of that solution to the initial situation and of comparing it with that situation. This can be illustrated by describing the way in which pupils are taught to use vectors in solving problems.

Problem. To prove that the three heights of a triangle or the extensions of those height intersect at a single point.

Let us introduce a vector system and translate the solution of the problem into vector language. To this end we construct the two heights AD and CE of the triangle ACB (Figure 1.1). We then find the point O where they intersect (or the point where there extensions intersect), connect the point O with the vertices of the triangle and consider the system of vectors. Recalling that $\overrightarrow{OA} = \vec{a}$, $\overrightarrow{OB} = \vec{b}$, $\overrightarrow{OC} = \vec{c}$, and that the scalar product of the orthogonal vectors $\overrightarrow{AB}$ and $\vec{c}$; $\overrightarrow{BC}$ and $\vec{a}$ is equal to zero, we obtain the two vector expressions $(\vec{b} - \vec{a}).\ \vec{c} = 0$, $(\vec{c} - \vec{b}).\ \vec{a} = 0$.

This completes the first stage of solving the problem. The second stage involves operating on the resulting vector expressions using known rules concerning vectors. The pupils are made to see that at this stage vector transformations are carried out without any thought of the meaning of the initial problem. In this problem the transformations must be carried out in such a way as to establish the perpendicularity of the vectors $\vec{b}$ and $\overrightarrow{CA}$. These transformations are as follows:

$$\vec{b}.\ \vec{c} = \vec{a}.\ \vec{c},$$
$$\vec{a}.\ \vec{c} = \vec{b}.\ \vec{a},$$
$$\vec{b}.\ \vec{c} = \vec{b}.\ \vec{a},$$
$$\vec{b}.\ (\vec{a} - \vec{c}) = 0 - \vec{b}.\ \overrightarrow{CA} = 0$$

Finally, from the latter equality and from the fact that neither vector $\vec{b}$ nor $\overrightarrow{CA}$ is a zero vector, we conclude that the third height likewise passes through the point O. This constitutes the third stage in the solution of the problem.

The second stage is the solution of the problem within the mathematical model constructed. It is this stage that has undergone the most extenive development in teaching practice in Soviet schools. It is based on the possibility of describing phenomena and processes in mathematical language, i.e. on the use of mathematical symbols; formulae, diagrams and drawings. The language of mathematics is the language of science and like any language it must be capable of clearly expressing scientific ideas and facts. That is why pupils must not only follow the clearly and logically presented oral and written material, but also devote due attention to the advisability of using the language of mathematics in the presentation of proofs and in the solution of problems, thus demonstrating the readibility of mathematical statements (image) and the convenience of working with them in the study of mathematics and other sciences.

The interpretation of the solution to a mathematical problem in accordance with the practical situation is the most important applied skill which must be developed systematically in the course of the pupil's entire school life. Thus, when studying whole numbers and using an equation to solve the problem in which the number of objects of a certain type must be determined; and on obtaining a fractional answer the pupil must understand that that answer does not correspond to the condition of the problem; using an equation to solve a problem involving the determination of the area of a figure and obtaining a negative root, pupils must realize that the area of a figure is necessarily a positive number; in solving an equation with a variable in the denominator, pupils must check the resulting solution in order to establish whether the meaning of the expressions entering into the equation for this or that value of the root has not been forfeited, etc.

Each of the three stages of solving a problem finds its due place in mathematics teaching inasmuch as it ensures an understanding of the use of mathematical theory and of the application of the knowledge and skills shaped in the course of the learning process. Familiarization with mathematical modelling proceeds in connection with various course units. The vector and coordinate methods afford considerable opportunities for their application to problem solving. Thus, the vector method enables one to deal with a fairly broad range of geometric problems (e.g. the problem of proving that straight lines and segments are parallel; the problem of proving the fact that a certain point breaks down a segment into two segments in a certain ration to one another; the problem of finding the magnitude of an angle). The coordinate method makes it possible to solve geometric problems algebraically, with constructions reduced to calculations. The use of the coordinate method involves the proper choice of the coordinate system, the determination of point coordinates, and the translation of the language of equations and inequalities into the language of geometry and vice versa.

The use of the vector method, just like the application of the method of coordinates, entails the following stages; (1) translation of the problem into vector or coordinate (analytical) language; (2) the transformation of the vector or analytical expression; (3) the inverse transformation, i.e. the conversion from vector or coordinate language into the language in whose terms the problem is formulated. For this reason, in solving problems by the indicated method, pupils must be able to do the following; a) to translate geometric terms into the language of the method (to be able to construct a mathematical model); b) to carry out the transformation from vector or analytical expresion; c) to carry out translation from vector or analytical language into the language of the problem. In addition to these general skills, pupils must develop skills of a more specific nature (for example, the ability to operate on vectors and the ability to determine the coordinates of specific points). The shaping of such general and more particular skills in pupils then serves as a basis for the study of vectors and the method of coordinates.

The development of scientific thinking in pupils is facilitated by such instruction techniques as work with models, the creation of problem situations, as well as an approach whereby the proof of a number of facts is preceded by observation involving the identification of general regularities and the statement of hypotheses (these hypotheses are formulated by the pupils themselves).

The use of models in the algebra course for grades VI-VIII became particularly popular among teachers upon the introduction of new programmes and textbooks in which illustrations employing models are one of the most effective and frequently used devices (in geometry such a method has been used as a matter of tradition).

Two separate ways of using models are distinguishable in mathematics teaching; models can either be used to explain concepts or to demonstrate theorem proofs and to solve problems. In the shaping of concepts the successful use of models enables pupils to find the required definition independently. All that is left for the teacher is to couch it in a logically correct form.

Let us cite an example of modelling of general reasoning techniques in the algebra course for grade VII. Having studied the topic "square roots", the pupil must be able to use the definition of the arithematic square root in proving theorems. Thus, the proof of the theorem of the square root of a product is presented in the textbook "Algebra, 7" as follows:

"Let us compare the values of the expressions $\sqrt{81 \cdot 4}$ and $\sqrt{81} \cdot \sqrt{4}$ -

$\sqrt{81 \cdot 4} = \sqrt{324} = \sqrt{18^2} = 18$,

$\sqrt{81} \cdot \sqrt{4} = 9 \cdot 2 = 18$.

We see that $\sqrt{81 \cdot 4} = \sqrt{81} \cdot \sqrt{4}$

Theorem 1: If $a \geq 0$ and $b \geq 0$ then $\sqrt{ab} = \sqrt{a} \cdot \sqrt{b}$ (1) (1)

To prove the validity of the equality.

for $a \geq 0$ and $b \geq 0$ we must establish that $\sqrt{a} \cdot \sqrt{b} \geq 0$ and $(\sqrt{a} \cdot \sqrt{b})^2 = ab$

Then on the basis of a definition of a square root one can assert that equation (1) is true for the given values of the variables. 1) The value of the product $\sqrt{a} \cdot \sqrt{b}$ is non-negative, so that according to the property of the square root for $a \geq 0$ and $b \geq 0$ each of the expressions a and b has meaning and assumes a non-negative value.
2) By virtue of the property of the power of the product we have

$$(\sqrt{a} \cdot \sqrt{b})^2 = (\sqrt{a})^2 \cdot (\sqrt{b})^2 = ab.$$

Hence, equation (1) is true.

Thus, the following property holds for an arithmetic square root: the root of the product of non-negative factors is equal to the product of the roots of those factors.

The theorem is likewise valid if the number of factors under the root sign is greater than two. The arithmetic square root of a fraction has a similar property.

As may be seen from the above excerpt, the proof of the theorem concerning the root of the product is based on the definition of an arithmetic square root. It consists of two parts:

1) It turns out that the value of the expression $\sqrt{a} \cdot \sqrt{b}$ is non-negative;
2) It is shown that the square of the expression $\sqrt{a} \cdot \sqrt{b}$ is equal to ab.

These two parts constitute the idea underlying the proof.

By constantly drawing the attention of pupils to the fact that there is always a certain idea underlying any proof, one provides a basis for independent searching for proof. In studying the point just discussed, pupils independently prove the theorem on the root of a fraction. Let us consider yet another example of the way in which the presentation of material in the algebra textbook for grade VII assists in having the pupils arrive at a general mode of reasoning. One of the difficult things in this section on quadratic equations is the derivation of the formula for the roots of a quadratic equation. The ability to solve a quadratic equation with the aid of a root formula constitutes one of the principal skills gained in the algebra course for grade VII. Without this ability, pupils will not be able to grasp the material presented at later course stages. The general derivation of the formula for the roots of a quadratic equation is preceded in the textbook "Algebra, 7" by a unit entitled "The solution of quadratic equations by identifying the square of a binomial" which plays an auxiliary role within the course. Its purpose is to help pupils understand the formula for the roots of a quadratic equation. For this reason it takes up the solution of three reduced quadratic equations, $x^2 + 6x + 5 = 0$, $x^2 - 5x + 8 = 0$, $x^2 - 18x + 81 = 0$. We have thus looked at the three cases which can occur when solving a quadratic equation: the first equation has two roots, the second does not have roots, and the third has a single root. The development of scientific thinking in pupils is also forstered by the presentation of textbook material in such a way as to help the teacher set up a problem situation. This can be explained by citing the example of the introduction of the definition of a power with a fractional exponent in the grade VIII algebra course. The extention of the notion of a power with a whole exponent to that of a power with a rational exponent is coupled in the "Algebra, 8" textbook with the construction of an exponential function. Having constructed the graph of the function $y = 2^x$, where $x \in Z$ and having connected the resulting points with a smooth curve, one has used the graph to specify a new function defined onthe set R.

The values of this function can be found from the formula $Y = 2^X$ for whole X only. If it should occur that the formula is also valid for computing the values of the function F in the case of fractional X, then one would have to assume that $2^{1/2} = 1.4$ etc. But the expressions $2^{1/2}$ $2^{3/4}$ are meaningless, since the notion of a power has been defined for a whole exponent only. The following problem arises; if we wish give meaning to such expressions as $2^{1/2} \cdot 2^{3/2}$ etc, then how advisable is it to define the notion of a power with a fractional exponent? Once the problem has been stated, one looks at the motives for defining a power with a fractional exponent. Such a consideration is based on the two following important requirements: the definition must be such that the basic property of a power $a^m \cdot a^n = a^{m+n}$ be maintained for the newly introduced concept of a power with a fractional exponent and that the power a^x with a fractional x be positive. These two requirements turn out to be sufficient for investigating the meaning of a power with a fractional exponent and adopting the appropriate definition.

The new algebra textbooks for grade VI-VIII make extensive use of a device of presentation whereby the proof of a number of properties is preceded by an observersation on the basis of which certain general regularities are noted and hypothesies expressed. This device turns out to be particularly effective in the presentation of the item "The function $y = 2^x$ " in the grade VIII algebra course. The following is an excerpt from this item:

"We have considered the properties of the function designated by the formula $y = 2^x$ on the set of real numbers . Now, having introduced the notion of a power with a rational exponent, we can consider a function given by the same formula on the set of rational numbers.

Let us compile a table of the values of the function $y = 2^x$ with the interval 1/4 (taking each successive value of x larger than the preceeding value by 1/4.)

Since $2^{1/2} = \sqrt{2} = 1.414$, it follows that

$$2^{1/4} = (2^{1/2})^{1/2} = \sqrt{\sqrt{2}} = 1.414 = 1189$$

knowing the values of the expression $2^{1/2}$ and $2^{1/4}$ we can find the value of the expression $2^{3/4}$

$$2^{3/4} = 2^{1/2 + 1/4} = 2^{1/2} \cdot 2^{1/4} \approx 1.414 \cdot 1.189 \approx 1.681$$

The values of the function corresponding to other values of x given in the table can be computed in the same way. For example,

$2^{3/2} = 2^{1\frac{1}{2}} = 2 \cdot 2^{1/2} \quad 2 \cdot 1.414 = 2.828$

$2^{-1/4} = 2^{-1+3/4} = 2^{-1} \cdot 2^{3/4} \approx 0.5 \cdot 1.681 = 0.8405$

$2^{-3/2} = 2^{-2+1/2} = 2^{-2} 2^{1/2} \approx 0.25 \cdot 1.414 = 0.3535$

Let us fill out the table, rounding off the resulting values of the expression 2^x to the nearest hundredth:

X	-2	$-1\frac{3}{4}$	$-1\frac{1}{2}$	$-1\frac{1}{4}$	-1	$-\frac{3}{4}$	$-\frac{1}{2}$	$-\frac{1}{4}$	0	$\frac{1}{4}$
y	0.25	0.30	0.35	0.42	0.50	0.59	0.71	0.84	1.00	1.19

x	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3
y	1.41	1.68	2.00	2.38	2.83	3.36	4.00	4.76	5.66	6.72	8.00

It is easy to see that any value of the variable given in the table is matched by a positive value of the expression 2^x and that a larger value of x corresponds to a larger value of the expression 2^x.

Let us prove that the functions defined by the formula $y = 2^x$ on the set of rational numbers has the following properties;

1) The function assumes positive values only;

2) The function is an increasing function.....

One of the opportunities for explaining to the pupil the role played by scientific methods as a means of looking at the world around us lies in the introduction of elements of history into the mathematics course for Soviet schools. The mathematics textbooks for grades IV-V contain brief historical notes which help the teacher to explain to the pupils what issues of practical life, including the requirements of mathematics itself, as well as those of other sciences and engineering, resulted in the development of particular branches of mathematics. This material gives the pupils a better grasp of certain epistemological isues in mathematics and the history of mathematics.

1.3. The polytechnical orientation of the mathematics course

Because of the extremely general way in which it reflects the real world, mathematics finds a broad range of practical applications and may therefore be considered a polytechnical discipline by its very nature. The polytechnical orientation of the mathematics course is stressed by means of appropriate programme content, by the manner of presentation of study material, by exercise content, and by the 'building in' of intersubject links.

The content of the present mathematics programme, including both the traditional and the new material (the properties of geometric transformations, the elements of vector algebra, the elements of mathematical analysis, the method of coordinates, etc.) opens up many opportunities to further intensify this polytechnical orientation of the physics course: the material in question markedly expands the pupil's understanding of the mathematical method used to describe and investigate real phenomena and events.

Particularly important in this connection is the use of specific examples to explain to the pupil the various characteristics of the way in which mathematics reflects regularities and mechanisms which operate in the real world. The learner is shown how mathematics can be used to study the world with which he is already familiar and is given an opportunity to develop skills and abilities required both in everyday life and in production. Methods of dealing with problems with the aid of modern investigative techniques taught in the classroom are linked to methods for solving practical problems and coping with practical situations.

One of the aspects of increased emphasis on the polytechnical orientation of mathematics instruction is the heightening of pupil skills in the use of algorithms with allowance for the principal current trends in the use of computers in modern industry and agriculture.

The new mathematics programme makes it possible to lend a systematic character to the training of pupils in the elementary use of algorithms beginning as early as in grade IV. For example, the grade IV mathematics textbooks present a step-by-step layout of algorithms for operating on decimal fractions:

"In order to add together decimal fractions, you must:

1) make the number of digits after the decimal point in each term equal;

2 write out the terms in a column in such a way that the decimal points are all lined up one below the other;

3) add together the resulting numbers just as you would add together a column of natural numbers;

4) place the decimal point in the sum obtained under the column of decimal points in the terms."

This rule constitutes the "exploded" layout of a linear algorithm.

Whereas pupils in grade IV are asked to find the most convenient way of computing specific formulae, pupils in grade V are required to perform similar tasks in a more general way. For example, in order to compare and then add or subtract fractions with different denominators, they are asked to:

" 1) find the least common denominator;

2) reduce each fraction to the least common denominator;

3) carry out the indicated operations."

In addition to formulae in "exploded" (verbal) form, the grade IV mathematics textbook also contains other ways of setting out algorithms. For example, in Section 16 entitled "Calculating numerical expressions", the order of operations is presented as in Figure 1.2. The pupils' ability to use this method of describing algorithms is enhanced by a set of exercises. In one of these, for example, they are required to construct an expression in accordance with the diagram of Figure 1.3. Another exercise involves carrying out a calculation in accordance with Figure 1.4, while yet another example entails performing operations in acccordance with the diagram in Figure 1.5 and providing an explanation of the result. The afore-mentioned exercises serve to demonstrate the method of organising numerical data in the form of a "tree" or graph.

The mathematical programme for grade V requires the pupil to master the combinatorial and permutational laws of addition, with the text stressing the fact that the use of these laws simplifies the process of calculation. The search for the simplest variant of a solution entails looking for a rational solving algorithm from among several algorithms, all of which are capable of yielding the same result.

The mathematics textbooks for grades IV and V also present another method of specifying algorithms - one which consists in filling out a table. The search for the solving algorithm consists in establishing a clear sequence of steps entailing the formal completion of a table. Such methods of specifying an algorithm enables pupils to understand algorithms as a set sequence of operations which have to be performed on numerical material in order to obtain an answer.

The grade VI algebra textbook provides ample opportunity to increase mastery of the algorithmic approach to mathematics. Thus, Section 26 uses specific examples in considering the number of solutions of a system of two linear equations in two variables. No formal investigative algorithm is suggested. The general method for solving systems of linear equations in two variables, namely the method of addition, is presented in Section 28.

The rule for multiplying a polynomial by another polynomial is set out in the following algorithm: "In order to multiply a polynomial by another polynomial, it is sufficient to multiply each term of the first polynomial by each term of the second polynomial and to add together the resulting products."

Work with tables continues in the algebra lessons in grades VI. The following example may be quoted: Given that the function g is a direct proportion, find the proportionality coefficient from the table. Specify the function g by a formula and fill out the following table:

x	-3	-1	1	3	5	7
y				6		

The algorithm for solving this problem runs as follows:

1) Find the value of the ratio of $\frac{6}{3}$

2) Write out the functional relationship between x and y
i.e. $y = 2x$

3) Calculate the values of y which correspond to the specified values of x to complete each column of the table. Pupils in grade VII are given an opportunity to master algorithms for solving equations and inequalities, as well as systems of equations and inequalities.

The school course in mathematics is intended to equip pupils with calculating skills adequate to present-day notions of what constitutes satisfactory computing ability.

Training in the carrying out of complex and cumbersome computations is no longer a requirement due to the rapidly expanding use of computer techniques. Another valuable feature of the new mathematics textbooks is the reduced number of rules which have to be memorized, the remaining rules being formulated in a form which is easy both to recall and to use.

Pupils learn to master the elements of computation at each level in the mathematics course, but a grasp of most of these elements is already ensured over the first five or six years of schooling. During this period pupils learn to make conscious use of the laws of mathematical operations (addition, subtraction, multiplication, division and raising to a power). In subsequent years the computational skills and abilities thus acquired are secured and enhanced through the study of mathematics, physics, chemistry and biology.

Another very important practical consideration is the development of an ability to carry out arithmetic operations on decimal fractions. A rough notion of the level of requirements set in exercises included in the unit on "Decimal fractions" in the grade IV mathematics course may be gleaned from the fact that pupils of the age level in question must be able to cope successfully with problems of the form:

1. Find the values of the expressions:

a) 73.2:30 - 20·1.2+30.8:200;

b) (181.3 - 65.7): 10-3 · (4.02-2.24);

c) 78·84: 52-22 + 9087:89.

2. Compare the values of the following expressions:

a) 7.14:7 + 1.3 · 0.6 and 3.06:1.5 - 0.26;

b) (72 · 205 - 120): 12-12+88 and 98·7 + 7·43;

c) 7.2:0.1+2·(0.82:0.4-0.35)and 1.5:0.2·10 + 0.04

The ability to use rational methods to carry out calculations is one of the more important facets of overall computing ability. Skill in carrying out calculations with the least possible effort and in the shortest possible time is a good indication of the level of mathematical development attained by the pupil. It is therefore no accident that examination problems in algebra have for a number of years included various exercises designed to test not only actual computing skill but also the ability to use the tools of algebra in order to carry out computation in a rational manner.

The transition to the new mathematics course contents for Soviet schools has entailed exposing the pupil to the polytechnical essence of mathematics at all levels of instruction, all the way from the introduction of a given concept to the construction of models of various real situations. Important aspects of this trend include the character of presentation of the theoretical material and the content of illustrations, problems and exercises.

It should be noted that modern algebra textbooks for grades VI-VIII make extensive use of various visual models, i.e. graphs, the coordinate plane and function graphs. The latter two types of representation had also been in use in the past. At the time, however, their purpose was largely to illustrate the properties of the functions under consideration. On the other hand, in the new course these models are regarded mainly as a means of giving shape to concepts and as a way of investigating the properties of a function. The graph of a function is relied upon for conveying any number of notions. For example, graphs are used to present the concepts of an increasing and decreasing function on a given set. The theorem whereby the graphs of mutually inverse functions are symmetric with respect to the straight line $y = x$ and the properties of the power function $y = 10^x$ are used to derive the properties of logarithms with the base 10.

The assignment of such a role to graphs in the study of functions is readily justifiable. The representation of a function by a graph in the form of a arbitrary continuous curve is something easily understood by pupils and helps them develop insight into the properties of numerical functions. The "readability" of a graph helps the learner to gain a secure grasp of the geometric essence of the properties of functions. At the same time, geometric notions of the properties of a function are sometimes not sufficient, which means that their analytical expression must be resorted to. The transition from geometric notions to analytic concepts is tantamount to the passage of a pupil to a new level of abstraction. In order for this initial passage to be successful, considerable preparatory work is required. This preparatory work takes the form of a study units involving the consideration of function graphs. For example, prior to formulating the definitions of an increasing and a decreasing function on a set, the grade VII algebra textbooks takes up six graphs of arbitrary functions (Figures 1.6, 1.7, 1.8, 1.9, 1.10, 1.11) using which pupils develop intuitive graphically visualized notions concerning these concepts. It is only after the latter have been grasped that pupils are asked to master the definitions of the same concept in analytical form.

The process of gaining insight to the concept of a function within the algebra course is effected not only by ensuring a mastery of functional notions, but also through the use of the expanding functional apparatus involved in the study of other sections of the course and the establishment of links between the notion of a function on the one hand and other topics on the other.

Thus, the property of monotonicity of a function is used extensively in solving various inequalities and in comparing the values of various expressions containing n th degree roots, decimal logarithms and powers with a rational exponent. In addition, quadratic inequalities are solved on the basis of their graphic representations.

Such use of functional concepts helps the pupil grasp the actual notion of a function and the necessity of functions and leads to a deeper and more conscious understanding of the polytechnical nature of the issue studied.

The new mathematics course has also been considerably enriched through the inclusion of problems of increased practical relevance.

Here are some examples of exercises directly related to the practical applications of geometry.

1) How many lengths of wallpaper are needed to paper the room whose dimensions are 6m x 5m x 3m, if the dimensions of a single length of wallpaper are 0.5m x 7m, assuming that areas of the windows and door correspond to the amount of wall

2) A roof has the shape of a pyramid with a square base with sides 4.5m x 4.5m, the angle between each of the faces of the pyramid and its base being equal to 45°. How many sheets of iron of dimensions 70 cm x 140 cm are needed to cover the roof if 10% of the total roof area must be added on to allow for trimmings?

3) Construction bricks 25cm x 12cm x 6cm in size are going to be used to build a wall. Find the volume of a wall made of 10,000 bricks. Assume that the gaps between the bricks increase the volume by 15%.

4) The construction of a hydroelectric power station involves the damming of a river bed with concrete blocks in the shape of regular truncated triangular pyramids of mass 10 t each. The height and sides of the base of each pyramid are proportional to the numbers 5, 2, 6. Calculate the linear dimensions of such a pyramid. (The concrete is of density 2.2 g/cm^3).

5) A railway embankment of height 2.8m is 10.1 m wide at the top and has a slope angle of 34°. Find the volume of a 1-km. straight segment of the embankment.

1.4. ANNEX 1

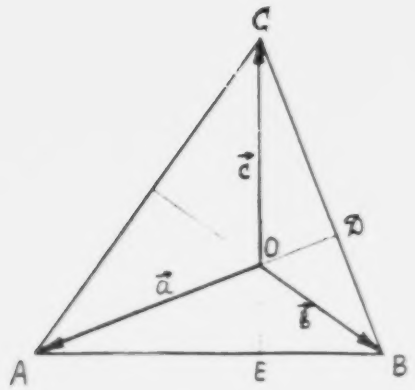


Figure 1.1

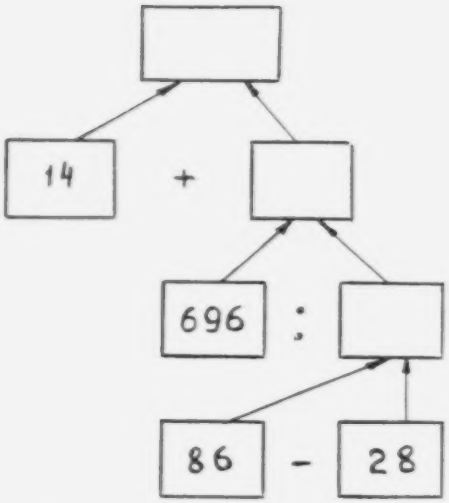


Figure 1.2

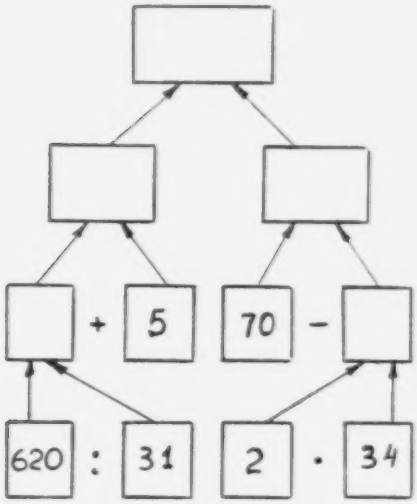


Figure 1.3

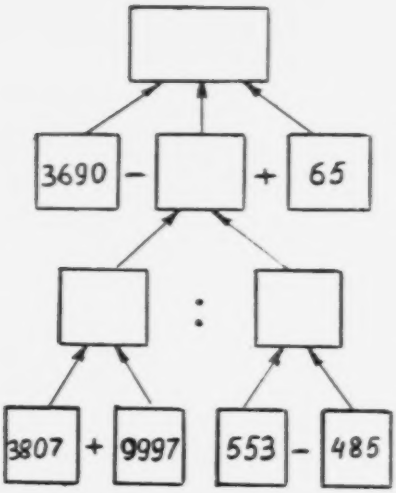


Figure 1.4

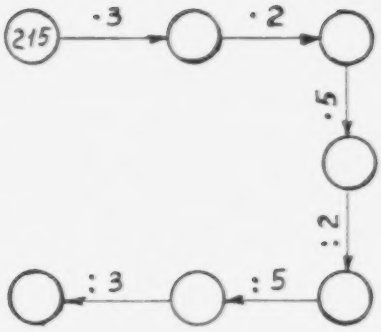


Figure 1.5

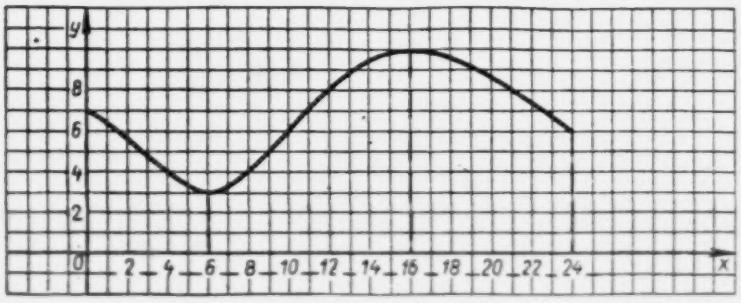


Figure 1.6

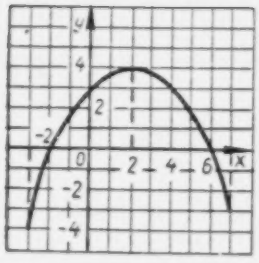


Figure 1.7

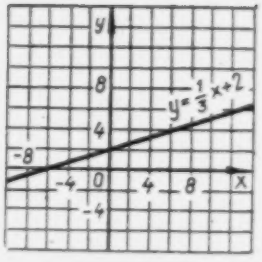


Figure 1.8

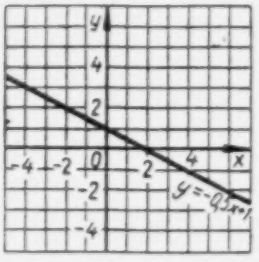


Figure 1.9

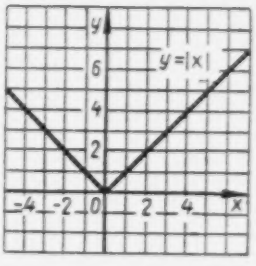


Figure 1.10

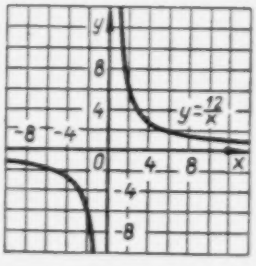


Figure 1.11

ANNOTATED BIBLIOGRAPHY

MATHEMATICS

Literature for the teacher

1. Programma po matematike dlya srednei obshcheobrazovatel'noi shkoly (The Mathematics Curriculum for the General Secondary School). Moscow, Prosveshchenie, 1982.

The mathematics curriculum for Soviet seconday schools consists of three sections: "Requirements in regard to the mathematics training of pupils", "Subject matter" and Thematic schedule of subject matter"..

The section entitled "Requirements in regard to the mathematics training of pupils" sets the expected level of attainment in mathematics for each stage of the mathematics course.

The section "Subject matter" specifies a stable minimum of material which must be covered within the school course.

The course contents are set out in this section not in the order of their presentation in any given textbook, but rather on the basis of "contents lines" which bring together closely interrelated topics.

The section entitled "Thematic schedule of subjet matter" sets out the way in which curricular subject matter is to be presented and indicates the time to be allotted to each topic or unit.

The purpose of the first two sections is to define a stable core of mathematical knowledge to be presented over a definite and sufficiently lengthy period of time (in the course of which no changes will be introduced into the appropriate section of the curriculum even if certain textbooks and study aids should be replaced or revised).

The specifics of textbooks and study aids in current use are reflected in the section entitled "Thematic schedule of subject matter", where the material specified in the "Subject matter" section is broken down by years and topics in the order in which they are to be studied in accordance with the textbook or study aid in question. Sample recommendations concerning the distribution of study time are also included.

The subject matter to be covered within each year is broken down into topics which are to be taken up in accordance with the indicated sequence. The relevant topics indicated in the "Subject matter" section are specified.

The methodological commentary sets out the basic purpose of studying each topic and gives recommandations as to how it may be dealt with. These recommendations include a description of the ways in which a topic is presented in a particular textbook. They likewise indicate the topics requiring special attention, describe supplementary material relevant to a given topic, and (in certain instances) specify the requirements to be met in mastering the relevant subject matter.

The level of specific requirements as to skills and abilities to be acquired by pupils is determined in large measure by the difficulty of the exercises set in a given textbook (more difficult supplementary exercises are not taken into consideration). In a number of instances the methodological commentary specifies the numbers of the relevant exercises which may be considered as defining this level.

An explanatory note specifies the objectives of mathematics training.

2. Markushevich, E.I. (ed), Matematika v 4 klasse: Metodicheskoye posobie dlya uchitelei (Grade IV Mathematics: A Methodological Aid for Teachers). Moscow, Prosveshchenie, 1982

This book is intended to assist the grade IV mathematics teacher using the new textbook Matematika, 4 (MATHEMATICS, 4). Also edited by Markushevich. It consists of an introduction, two chapters and an appendix. The chapter, section and item headings coincide with those of Matematika, 4 Each item is broken down into the same sub-items, namely knowledge and skills; method of presentation; comments on exercises; oral exercises. Each section is followed by quiz questions, supplementary exercises and sets of test assignments.

The section "Knowledge and skills" describes the knowledge and skills to be acquired by a pupil who has successfully covered the material in the given item. Such a capsule presentation of basic knowledge and skills enables the teacher to highlight the most important material to be mastered by the pupil. Its contents are also useful in assessing pupils' grasp of a subject matter already covered.

The "Method of presentation" section presents a methodological analysis of contents, explains why the subject matter is to be presented in the way suggested, justifies the placement of the given topic within the course sequence and defines the purpose of the system of exercises permitting the pupil to gain mastery of the proposed material. In this section the teacher can find recommendations of an organizational character, comments concerning presentation techniques and exercise sequences, as well as remarks concerning the preparation of a given lesson and the use of additional reference materials, technical resources and demonstrations.

The section "Comments on exercises" contains remarks concerning the exercises which require particular attention, including those to be dealt with in the classroom when presenting new material or reviewing subject matter already covered. Other comments concern homework assignments and the checking of homework.

Occasionally several solutions of the same problem are presented and discussed.

The oral exercises suggested in the teachers' aid are not consecutively numbered, but are denoted by a letter and parenthesis within each text item. This makes it easier for the teacher to carry over the given exercise to the next lesson or lessons, and to regroup exercises within a single lesson or series of lessons as he sees fit. In order to avoid restricting the teacher unduly, the oral exercises are set out in the form of a separate group for each individual item. The answers to each exercise problem are given immediately following the latter in square brackets.

Each section is followed by a set of questions designed to test pupils' mastery of the material just covered within that section. These questions, printed in bold-face type, encompass the entirety of the textbook material already covered.

Supplementary exercises are given at the end of each section in order to facilitate work with pupils who have missed one or more lessons or who have not managed to master the required material.

Each section is likewise followed by two suggested written assignments. These are intended to test mastery of the required basic material. Each assignment set consists of five exercises, followed by the appropriate answers.

3. Markushevich, A.I. (ed.), Matematika v 5 klasse: Metodicheskoe posobie diya uchitelei (Grade V Mathematics: A Methodological Aid for Teachers). Moscow, Prosveshchenie, 1982.

This book is designed to assist the grade V mathematics teacher using the new Matematika, 5 textbook (also edited by Markuschevich).

The structure of the guide is similar to that of the previous title.

4. Makarychev, Yu. N., Mindyuk, N.G., Muravin, K.S. et all., Algebra v 6 klasse: Metodicheskoe posobie diya uchitelei (Algebra in Grade VI: A Methodological Aid for Teachers). Moscow, Prosveshchenie, 1977.

The book is intended to assist the teachers using the Algebra, 6 textbook (by the aforementioned authors, and edited by Markushevich).

It consists of an introduction, five chapters and an appendix. The chapter section and item headings are the same as those of the textbook itself. Each item is structured according to the same pattern: knowledge and skills, methodological recommendations, comments concerning exercises and oral exercises. A series of review questions is given at the end of each section. Each chapter ends with comments on the supplementary exercises.

The book contains methodological recommendations concerning the presentation of theoretical materials, comments on the exercises, a sample schedule of topic presentation, and assignments for independent work, testing and review.

5. Makarychev, Yu.N., Mindyuk, N.G., Muravin, K.S. et al. Algebra v 7 klasse: Metodicheskoe posobie diya uchitelei (Algebra in Grade VII: A Methodological Aid for Teachers). Moscow, Prosveshchenie, 1978.

The book is intended for teaches using the Algebra, 7 textbook (by the aforementioned authors and edited by Markushevich).

It consists of an introduction, four chapters and an appendix. The chapters are broken down into sections and the sections into items. The chapter, section and item headings are the same as those of the textbook. Each item consists of the following sub-items: knowledge and skills, methodological recommendations, comments concerning exercises and oral exercises. Comments concerning the supplementry exercises appear at the end of each chapter

6. Makarychev, Yu. N, Mindyuk, N.G., Monakhov, V.M. et al. Algebra v 8 klasse: Metodicheskoe posobie diya uchitelei (Algebra in Grade VIII: A Methodological Aid for Teachers). Moscow, Prosveshchenie, 1979.

The book is intended to assist the teacher using the Algebra, 8 textbook published in 1979 (by the aforementioned authors, and edited by Markushevich).

It consists of an introduction, six chapters and an appendix. The contents include methodological recommendations on the presentation of theoretical material, comments on the exercises, a sample schedule of topic presentation, and quiz and test material.

Methodological guides for teachers do not place sufficient emphasis on the school mathematics course in the general intellectual development of the child, nor do they discuss the methodology involved in using various types of visual aids and other resources. Another omission has to do with the fact that they do not deal with certain general educational issues. In this regard the present teacher's aid fills an important gap in the literature designed to help algebra instructors in the eight-year school.

8. Gusev, V.A. (compiler). Prepodavanie geometrii v 6-8 klassakh: Sbornik statei (The Teaching of Geometry in Grades VI-VIII: A Collection of Articles). Moscow, Prosveshchenie, 1979.

The articles in this collection deal with certain aspects of geometry instruction in the eight-year school. In addition to such general issues as inter- and intrasubject links, making lessons more effective, and the ways of using problems as a tool for skill development, the authors also discuss various particular facets of geometry teaching, e.g. vectors, geometric transformations, logical principles and problem solving.

9. Glagoleva, E.G. and Ivashev-Musatov, O.S. (compilers). Voprosy prepodavaniya algebry i nachal analize v srednei shkole: Sbornik statei (The Problems of Teaching Algebra and Elementary Calculus in the Secondary School: A Collection of Articles). Moscow, Prosveshchenie, 1980.

The articles in this collection deal with various methodologies for coping with the challenging and important problems of teaching algebra and elementary calculus in grades IX and X. The author's recommendations are based on actual teaching experience.

10. Skopets, Z.A. and Khabib, R.A. (compilers). Prepodavanie geometrii v 9-10 klassakh: Sbornik statei (Geometry teaching in Grades IX and X: A Collection of Articles). Moscow, Prosveshchenie; 1980.

The present collection consists of two parts, one dealing with particular methodological problems encountered in the teaching of solid geometry and the other with general methodological issues. The articles concern such matters as the wider use of the apparatus of vector algebra in the study of a number of problems of solid geometry, various ways of presenting the section on "Volumes and areas of polyhedra and bodies of rotation", a unified approach to the study of the properties of transformations of a plane and a space, and ways of improving the effectiveness of instruction in solid geometry.

11. Ponomarev, S.A., Stratilatov, P.V. and Syrnev, N.I., Sbornik zadach po matematike dlya 4-5 klassov. Posobie dlya uchitelei (Collection of Mathematics Problems for Grades IV and V). Moscow, Prosveshchenie, 1979.

This collection of problems was prepared in accordance with the new mathematics curriculum and textbooks for grades IV and V and is designed as a supplement to the latter.

The contents of the collection are set out in the same order as in the textbooks, except that the geometry topics are grouped together in a separate chapter for each grade (year) in accordance with the order followed in the standard textbooks. Reference material is presented in an appendix.

12. Gusev, V.A., Maslova, G.G., Skopets, Z.A. and Cherkasov, R.S., Sbornik zadach po geometrii dlya 6-8 klassov (A Collection of Geometry Problems for Grades VI-VIII). Moscow, Prosveshchenie, 1979.

This collection supplements the geometry textbook used in the eight-year school. It consists of two parts. The first part contains problems and questions which can be used in first presenting, reviewing and developing the subject matter. The problems involve computation, construction and proof. Much attention is devoted to exercises designed to develop logical thinking by pupils. Many of the problems, exercises and questions are intended to enhance visualization and conceptualization in three dimensions.

The second part of the collection contains more difficult problems whose solution calls for non-standard approaches.

13. Gerasimova, I.S., Gusev, V.A., Maslova, G.G., Skopets, Z.A. and Yagodovskii, M.I., Sbornik zadach po geometrii dlya 9 i 10 klassov (A Collection of Geometry Problems for Grades IX and X). Moscow, Prosveshchenie, 1977

The geometry textbooks used in grades IX and X contain the amount of problem material necessary in teaching solid geometry. The problems contained in them reflect the level of difficulty and the variety appropriate to the study of this subject. However, the modern course in solid geometry incorporates a number of new topics and approaches not found in the old course. There is still a dearth of problem collections and teachers' guides ("aids") containing exercises and problems designed to develop skills in the application of theoretical propositions. The present collection goes some way towards filling this gap. It includes problems relating to all sections of the course, problems for out-of-class and individual work, and problems and exercises for the review of topics covered in plane geometry.

14. Iviev, B.M., Zemlyakov, A.N., Tomashevich, F.V. and Kalinichenko; Yu. V., Sbornik zadach po algebra i nachalam analiza dlya 9 i 10 klassov (A Collection of Algebra and Elementary Analysis Problems for Grades IX and X). Moscow, Prosveshchenie, 1978.

This collection is designed to assist mathematics teachers in the senior grades. It contains problems corresponding to the course in algebra and elementary analysis for grades IX and X of the general secondary school, as well as problems for out-of-class and individual work with pupils. Some of the problems help the teacher to convey basic concepts and facts to be mastered by pupils taking the course.

15. Abramov, A.M., Gusev, V.A., Maslova, G.G. et al. (compilers), Geometriya v 6 klasse: Posobie dlya uchitelei (Geometry in grade VI: An Aid for Teachers). Moscow, Prosveshchenie, 1980.

This guide is intended for use by teachers using the Geometriya, 6-8 textbook by Kolmogorov, Semenovich and Cherkasov. It contains brief methodological recommendations on the presentation of theoretical material, a sample lesson schedule, and sample tests and quizzes.

The book consists of an introduction, two chapters corresponding to the chapters of the standard textbook, and an appendix.

The introduction sets out the basic concepts of the textbook and gives general methodological advice on its use.

The first and second chapters of the book are devoted to a methodological analysis and commentary of the appropriate sections of the textbook.

The appendix contains a suggested plan of instruction and sample tests and quizzes for the grade VI geometry course.

16. Gusev, V.A., Maslova, G.G., Semenovich, A.F. et al (compilers), Geometriya v 7 klasse: Posobie dlya uchitelei (Geometry in Grade VII: An Aid for Teachers). Moscow, Prosveshchenie, 1981.

This guide contains brief methodological recommendations for the use of the Geometriya 6-8 textbook (by Kolmogorov, Selmenovich and Cherkasov) in grade VII. It consists of an introduction, four chapters corresponding to Chapters III-VI of the textbook, and an appendix.

The introduction points out the basic ideas used in preparing the textbook, general methodological suggestions concerning geometry instruction in grade VII and the use of the textbook both in and out of the classroom.

The rest of the material in the guide is a methodological analysis of and commentary upon the corresponding textbook sections.

17. Pontryagin, L.S. Znakomstvo s vysshei matematikoi. Analiz beskonechno malykh (Becoming Acquainted with Higher Mathematics. The Infinitesimal Analysis). Moscow, Nauka, 1980.

This book concerns certain aspects of analysis. One special feature is that it deals with the theory of functions of a real and a complex variable simultaneously.

It consists of an introduction and four chapters.

Literature for the pupil

1. Vilenkin, N.Ya;. Neshkov, K.I., Shvartsburd, S.I. et al. Matematika: Uchebnik dlya 4-go klassa srednei shkoly (Mathematics: A Grade IV Textbook). Moscow, Prosveshchenie, 1982.

This textbook was prepared in accordance with the new mathematics curriculum for grade IV as approved by the USSR Ministry of Education. It contains two sections entitled "Natural numbers and fractions" and "Decimal fractions". Elementary notions concerning geometry are presented in both sections.

The explanations in the textbook are followed by sets of exercises, i.e. the two types of material are presented side by side rather than in separate sections. Each opening section consists of an explanation in the form of thoretical information illustrated by examples. The method of presentation is inductive. As a rule, each explanatory passage is followed by the formulation of a general proposition (a definition, a rule, etc.) on the basis of a specific example. This is followed by another example to illustrate the general proposition. Then comes a battery of exercises covering the material in the given section.

The next two sections are entitled "Review exercises" and "Homework exercises". The former contains exercises helpful in reviewing the material in the previous section, as well as exercises covering "older" material. Each numbered asignment consists of several exercises.

Each of the chapters in the textbook is followed by an extensive set of review exercises.

The final sections of the textbook have self-explanatory titles: "How people learned to count", "How geometry arose in the first place", "Some more challenging problems" and "Some important things to remember from mathematics in grades I - III".

2. Vilenkin, N.Ya, Neshkov, K.I., Shvartsburg, S.I. et al., Matematika: Uchebnik dlya 5 -go klassa srednei shkoly (Mathematics: A Grade V Textbook). Moscow, Prosveshchenie, 1982.

This textbook was prepared in accordance with the new mathematics curriculum for grade V as approved by the USSR Ministry of Education.

The textbook is structured in the same way as the mathematics textbook for grade IV.

It contains sections entitled "Positive and negative numbers" and "Rational numbers". Both sections contains information concerning elementary geometry. Each item is rounded off by sets of review and homework exercises.

3. Makarychev, Yu.N;, Mindyuk, N.G. and Muravin, K.S., Algebra: Uchebnik dlya 6-go klassa srednei shkoly (Algebra: A Grade VI Textbook). Moscow, Prosveshchenie, 1982.

This textbook was prepared in accorance with the new mathematics curriculum for grade VI as approved by the USSR Ministry of Education.

The textbook consists of five chapters: "Basic concepts", "Functions", "Systems of equations", "Power with natural-number exponents", "Polynomials". Each chapter is broken down into sections, and each section into items. Each item contains theoretical information and relevant exercises.

Considerable emphasis in the textbook is placed on systematic review. This is made possible not only by exercises in which new material is organically linked with material previously covered, but also by the inclusion of special review exercises. These require pupils not only to reproduce earlier material, but also to make sense of it at a higher level.

In addition to the basic exercises, virtually every item is accompanied by supplementary exercises appearing at the end of the chapter.

At the end of the textbook is a section entitled "Difficult problems". This consists of exercises intended for out-of-class work with pupils who exhibit a heightened interest in mathematics.

The algebra course for grade VI is structured as an extension of the mathematics courses for grades IV and V. The appropriate concepts are conveyed along three basic conceptual lines, namely that of identity transformations, that of equations and inequalities, and that of functions.

The polytechnical orientation of the course is reflected in the fact that a mathematical apparatus is built up for describing and investigating various processes. In addition, the pupil is encouraged to develop useful practical skills (the ability to calculate using rational numbers, to construct and to read graphs, and to proceed from models to generalizations).

4. Pogorelov, A.V., Geometriya: Uchebnoye posobie dlya 6-10-go klassov srednei shkoly (Geometry: A Textbook for Grades VI-X.) Moscow, Prosveshchenie, 1982.

This textbook is a systematic presentation of the geometry required by the new curriculum. It covers both the traditional aspects of plane and solid geometry and new material (coordinates, vectors, transformations) whose presentation is based on an original system of axioms. This system of axioms is remarkable for its economy, making it possible to construct the main body of the geometry course and to encompass all of the basic facts of geometry.

The system of review questions enables pupils to use the textbook for independent study. The questions themselves highlight the most important theoretical points while at the same time enabling the pupil to gauge his own progress.

5. Kolmogorov, A.N., Semenovich, A.F. and Cherkasov, R.S., Geometriya: Uchebnoye posobie dlya 6-8 klassov srednei shkoly (Geometry: A Textbook for Grades VI-VIII), Moscow, Prosveshchenie, 1982.

This textbook contains theoretical and problem material corresponding to the geometry curriculum for grades VI-VIII.

The book consists of ten chapters subdivided into sections. Each chapter ends with a set of supplementary problems.

Historical information is included both in the texts of the appropriate sections and in the form of separate sections devoted entirely to history.

6. Makarychev, Yu. N., Mindyuk, N.G., Muravin, K.S. et al, Algebra: Uchebnik dlya 7-go klassa srednei shkoly (Algebra: A Textbook for grade VII). Moscow, Prosveshchenie, 198.

This textbook was written in accordance with the mathematics curriculum for grade VII as approved by the USSR Ministry of Education.

It consists of four chapters, entitled "Rational fractions", "Inequalities", "Approximations" and "Square roots and quadratic equations". The chapters are broken down into sections and the sections into items. Each item contains theoretical information and exercises. In addition to the basic exercises virtually every item is accompanied by supplementary exercises which appear at the end of the chapter. The basic sets of exercises do not include problems involving cumbersome transformations or artificial devices ("special tricks"). Apart from exercises involving computation, considerable stress is placed on graphic problems, practical questions, and exercises which call for the use of mathematical tables.

The final portion of the book is devoted to "Difficult problems" intended for pupils who are particularly interested in mathematics.

The algebra course for grade VII goes deeper into identity transformations of expressions, equations, inequalities and functions.

7. Makarychev, Yu.N., Mindyuk, N.G., Monakhov, V.M. et al., Algebra: Uchebnoe posobie dlya 8-go klasa srednei shkoly (Algebra: A Textbook for Grade VIII). Moscow, Prosveshchenie, 1982.

This textbook was written in accordance with the new mathematics curriculum for grade VIII as approved by the USSR MInistry of Education.

It consists of six chapters entitled "Quadratic functions", "Equations and inequalities in two variables", "Arithmetic and geometric progressions", "Powers with a rational exponent", "The exponential function" and "Decimal logarithms: the organization of computations. The chapters are broken down into sections and the sections into units containing theoretical information and exercises.

Considerable emphasis in the textbook is placed on the review and systematization of subject matter already covered. This is done both by presenting new material in an appropriate manner and by a suitable system of exercises in which new material is related in a close-knit way with materials previously studied. In addition, each item includes special review exercises.

The final section of the book, entitled simply "Review", includes exercises on all topics. In addition to the basic exerises each chapter contains additional exercises, some of which duplicate the basic course exercises, as well as more difficult problems pertaining to the contents of the chapter in question.

The algebra course for grade VIII is so structured as to serve as an extension of the algebra course in the earlier grades. The study of functions, equations, inequalities, identity transformations and computation is resumed and developed on the basis of material already covered.

The course requires the pupil to deal with various types of exercises involving computation, the construction of function-value tables, and calculation using logarithms and a slide rule. The concept of an algorithm is introduced and illustrated with examples. The subject of computer-assisted calculations is introduced for the first time.

Various problems in applied mathematics are presented and discussed. The concept of an algorithm and the use of computers for calculations receive considerable emphasis.

8. Kolmogorov, A.N., Abramov, A.M., Veits, B.E. et al., Algebra i nachala analiza: Uchebnoe posonie dlya 9 i 10 klasov srednei shkoly (Algebra and Elementary Calculus; A Textbook for Grades IX and X). Moscow, Prosveshchenie, 1982.

This textbook follows the new mathematics curriculum for grades IX and X as approved by the USSR Ministry of Education. It contains the material required for both the algebra and the calculus segments of the course in a single volume.

It consists of six chapters, each of which is subdivided into sections and items. The theoretical passages include material set in special type (theorems are highlighted by the use of semi-bold italics and definitions by ordinary semi-bold type). Virtually every item includes examples of the basic types of exercises pertaining to the given text.

At the end of the book is a section entitled "Review material" which contains basic information from the algebra course for grades VI-VIII. This material is intended both as an aid for organized review and as a basis for independent work by the pupil. The sections entitled "Reference material", "Subject index" and "Explanation of signs and symbols" make it easier for both teacher and pupil to work with the book.

The textbook contains not only theoretical material, but also exercises which appear at the end of each unit. In addition, "Supplementary exercises" are given at the end of each chapter. These exercises correspond to the theory presented in the chapter and are designed to help the pupil secure an even better grasp of the relevant concepts, theorems and methods.

The section entitled "More difficult problems" is designed for individual work with pupils. There is still more material (marked) for the pupil who is deeply interested in mathematics.

The textbook was written in such a way as to render its contents as readable and understandable as possible. Thus, the readily grasped definition of the derivation as the tangent of an angle formed with the *Ox*-axis by the tangent to a curve is used to acquaint pupils with the theorem of Lagrange, which is then applied immediately to prove the criterion of monotonicity of a function over an interval, as well as to derive the criterion of constancy of a function. (The Lagrange theorem is introduced in the chapter entitled "The derivation and its applications", while the constancy criterion is presented in the next chapter, entitled "Primitives and integrals".)

The treatment of the integral includes its conceptualization as the area of a curvilinear trapezoid. The Newton-Leibniz formula is introduced on the basis of intuitive notions concerning area.

Intuitive notions are also used to derive the formulas for the derivatives of an exponential and a logarithmic function.

9. Klopskii, V.M., Skopets, Z.A. and Yagodovskii, M.I., Geometriya: Uchebnoe posobie diya 9 i 10 klassov srednei shkoly (Geometry: A Textbook for Grades IX and X). Moscow, Prosveshchenie, 1982.

This textbook was written in accordance with the new mathematics curriculum for grades IX and X and contains the material for both years in a single volume.

The conceptual basis of the old geometry course has been retained, the subjects covered including the concepts of set theory, mapping and maps of figures and the axiomatics of A.N. Kolmogorov. The stereometric representation of figures is dealt with in readily understandable inductive terms.

The book consists of six chapters subdivided into sections and items. Each item is followed by a set of exercises and each chapter by a set of review problems. The basic contents are followed by three special chapters entitled "Historical outline", "Brief summary of plane geometry" and "Problems for review"

The history chapter contains intresting problems set by mathematicians over the ages, as well as several theorems (Ptolemy's theorem, Euler's theorem on polyhedra, Lobachevskii's non-Euclidean geometry theorems).

The chapter entitled "Brief summary of plane geometry" contains both theory and detailed solutions of several problems in applied plane geometry. Exercises calling for constructions and proofs are also included.

The chapter "Problems for review" contains problems pertaining to the material for both grades (years).

10. Pontryagin, L.S.., Znakomstvo s vysshei matematikoi. Metod koordinat (Becoming Acquainted with Higher Mathematics. The Method of Coordinates). Moscow, Nauka, 1977.

This work presents the methods of coordinates largely as it applies to plane analytical geometry. Other aspects dealt with include algebra, the geometrical representation of complex number and polynomials as complex functions of a complex variable. This makes it possible to give the proof of the Fundamental Theorem of Higher Algebra. There is also a cursory treatment of three-dimensional Cartesian coordinates and solid analytical geometry.

The book deals with issues in higher mathematics in a manner accessible to the pupil in the two final grades of secondary school.

11. Pontryagin, L.S., Matematiceskii analiz diya shkol'nikov (Mathematical Analysis for Secondary-School Pupils). Moscow, Nauka, 1980.

This brochure is a brief introduction to mathematical analysis, covering all aspects of this subject as dealt with in the secondary school. Topics discussed include the products of polynomials and trigonometric, exponential and logarithmic functions. Integration is defined as the inverse of differentiation, as the area of a graph, and as the limit of a finite sum. Exercises corresponding to each section of the text are given at the end of the book. The emphasis is on computer techniques rather than on rigour of exposition.

2.0. PHYSICS

2.1. Recent Trends in the Modernization of Physics Teaching in the Soviet Union.

Present trends in the modernization of physics instruction are related, first and foremost, to the introduction of universal and obligatory secondary education throughout the Soviet Union, and with the increasing role of science in the advance of engineering and technology.

Until the introduction of universal obligatory secondary education, the principal role of the secondary school consisted in preparing young people for entry into higher educational establishments.

Since then, the functions of the secondary school have broadened considerably. The school programme provides for the continuation of education, not only in higher educational institutions, but also in middle-level professional and occupational schools. It likewise prepares the young person for socially useful labour regardless of the choice of occupation, at the same time preparing him, or her, for a conscientious and independent everyday existence. This explains the increasing importance of physics as a general educational component of secondary school education, as a means of promoting the intellectual development of pupils, and of shaping a scientific world outlook, and also as an essential ingredient of polytechnical education and preparation for working life.

The physics course in Soviet schools consists of two levels and lasts five years. Some difficult subjects such as wave optics and quantum physics are not studied at the first-stage level, and are begun only at the second stage. Other topics such as hydrostatics are covered in their entirety in the first stage. In other words, such subjects are not reviewed at the second-stage level. Various types of oscillations and waves are studied only at the second-stage level of grade X.

Such step-by-step coverage of course material helps to develop pupil interest in a given subject, to develop cognitive capabilities, and to ensure successful mastery of the course material by all class members. In accordance with the didactic principle of gradually increasing difficulty, the complexity of subject matter increases from grade to grade. The number of lessons per week and per annum likewise increases. This may be seen from the following table:

TABLE I

	FIRST STAGE				SECOND STAGE	
Grade	VI	VII	VIII	IX	X	TOTAL
Number of lessons per wk./ Number of lessons per annum	2/68	2/68	3/102	4/136	4.5/154	15.5/528

The first step of physics training (grades VI, VII) comprises several important objectives, i.e., awakening interest in the subject, equipping pupils with elementary notions and developing their ability to think scientifically, and preparing them for the systematic coverage of course material to be offered at the second-stage level. The contents of the first-stage course provide for mastery of such basic physical notions as mass, force, energy, work, temperature, pressure, current, resistance, voltage, field, etc., which constitute the "building blocks" of all subsequent topics in this field.

Having mastered these basic concepts, pupils embark on the study of such phenomena, laws of physics, and practical applications of these laws as mechanical motion, determining the mass of a body using a scale, studying the phenomenon of gravity, the pressure of a liquid and a gas, the equivalence of work performed with the aid of machines and mechanisms, thermal motion, methods of changing internal energy, changes in the aggregate state of a substance, Ohm's law for part of a circuit, the magnetic field around a conductor, the AC electric motor, electromagnetic induction, the generator, etc.

The second stage of the physics course (Grades VIII-X) is built up on the basis of fundamental physical theories (classical mechanics, molecular physics with elements of thermodynamics and electrodynamics together with the basic notions of the special theory of relativity, and quantum physics). These fundamental physical theories make it possible not only to systematize and generalize the study material; in fact, they constitute tools enabling pupils to master many of the issues raised in modern science and its engineering applications. Among other things, the second stage involves examining such problems as the motion of a body under the action of elastic, gravitational and friction forces; the motion of artificial earth satellites; the weight of an accelerating body; weightlessness and g-forces; jet propulsion and the lift of an aircraft wing; the equation of state of an ideal gas and its particular instances for constant temperature, volume, the pressure values; the principle of action of thermal engines; the maximum efficiency of a thermal engine; the use of electrolysis in technology and the cathode ray tube; semiconductor diodes and triodes; the principle of action of electrical measuring instruments; resonance and its use in technology; the valve generator; the principle of radiotelephony; radar; television; optical instruments and their use in technology; the law relating mass and energy; the photoelectric effect and its application; lasers; nuclear and thermonuclear reactions; the nuclear reactor; the transformation of an electron-positron pair into gamma radiation, etc.

A list of the principle units and topics of the physics programme for the general educational school is presented in Table 2 below.

TABLE 2

Grade	Unit	Topic	No. of hours
VI (68 hrs)		Introduction	
		Initial information concerning the structure of matter.	
		Motion and forces	
		Liquid and gas pressure (hydrostatics and aerostatics)	
		Work and power. Energy	
		Field trip	
VII (68 hrs)	Thermal phenomena	Heat transfer and work	
		Changes in the aggregate states of matter	
		Thermal engines	

	Electricity	The structure of the atom Strength of current, voltage, resistance. Work and electric power Electromagnetic effects Field trip
VIII (102 hrs)	Mechanics	Elements of kinematics (relativity of motion, trajectory, path length, translational motion, velocity, acceleration) Fundamentals of dynamics (Newton's laws, elastic, frictional, and gravitational forces) Applications of the laws of dynamics. Elements of statics Conservation laws Mechanics and mechanization of production Physics workshop Field trip
IX (136 hrs)	Molecular Physics	Principles of molecular-kinetic theory (Brownian motion, velocity, mass and sizes of molecules, Avogadro's number, the fundamental equation of molecular-kinetic theory for an ideal gas, temperature, equation of state of an ideal gas). Thermal effects. The First Law of Thermodynamics (the amount of heat and work as measures of change in the internal energy) the First Law of Thermodynamics, (the principle of action of thermal engines).

		Properties of gases, liquids and solics (saturated and unsaturated vapors, air humidity, the surface tension of a liquid, crystalline bodies, mechanical properties of solids).
	Electro-dynamics	The electric field (intensity, potential difference, voltage, electrical capacity)
		Direct-current laws (the electro-motive force, Ohm's law for a closed circuit)
		Electrical current in various media (current in metals, electrolytes, gases, vacuum and semi-conductors)
		The magnetic field
		Electromagnetic induction
		The basic laws of electrodynamics and their technical application
		physics workshop
		Field trip
X (138 hrs)	Oscillations and waves	Mechanical oscillations (harmonic oscillations, the pendulum, displacement, period, frequency and phase, resonance, auto-oscillations).
		Electromagnetic oscillations (alternating current, impedance, capacitive and inductive resistance, the triode, the valve oscillator).
		Generation, transmission and use of electrical energy
		Mechanical waves
		Electromagnetic waves

Optics	Geometric optics (the laws of illumination, reflection and refraction; optical instruments)
	Light waves
	Elements of the theory of relativity
	Radiation and spectra
Quantum Physics	Light quanta. Light action
	The atom and its nucleus (Rutherford's model of the atom, the experiments of Franck and Hertz, radioactivity, the binding energy of atomic nuclei, the transformation of an electron-position pair into gamma radiation);
	General lectures: physics and the revolution in science and technology; the scientific map of today's world.
	Physics workshop
	Field trip
	Review

The generalization of pupils' knowledge on the basis of fundamental physical theories helps to shape a scientific way of thinking. This process is assisted by familiarizing pupils with the structural elements of physical knowledge such as phenomena, experiments, concepts, laws, theories, and the practical application of theory.

The programme is accompanied by a bill of requirements as regards subject matter to be mastered. In other words, the pupil is required to gain a grasp of the following:

Physical phenomena:

- the attributes of a phenomenon which render it detectable or recognizable:
- the conditions under which the phenomenon transpires;
- the connection or connections between a given phenomenon and other phenomena;
- examples of the practical use of the phenomenon;

Physical experiments:

- aim, scheme, course and results of an experiment;

Physical concepts, including physical quantities:

- phenomena or properties characterized by a given concept;
- definition of a concept;
- formulae relating to a given quantity to other quantities;
- means of measuring a quantity;

Physical laws:

- formulation and mathematical expression of a law;
- experiments which confirm its validity;
- examples of its use in practice;
- conditions of applicability of a law;

Physical theory:

- experimental justification of a theory;
- basic concepts, models, laws, principles;
- basic implications or consequences;
- practical applications;
- limits of applicability;

Instruments, mechanisms and machines:

- principles of action and scheme of operation of a device;
- function or purpose;
- examples of use.

Because it is so important for pupils to develop cognitive abilities and a capacity for thinking scientifically, it is essential that the physics course reflect the methodological importance of research methods, ideas, hypotheses, models, creative reasoning, and experiments and practical applications of scientific knowledge. The physics course for Soviet schools is grounded on sound theoretical foundations in conformity with the epistemological ("gnoseological") conception of dialectical materialism, whereby one proceeds from basic fact to a hypothesis (comprising a model of the phenomenon, basic concepts, laws and principles) to a theoretical conclusion concerning consequences or effects, and then to the experimental verification of these consequences or effects. This means that the historical process of scientific inquiry is, so to speak, built into the school course.

The incorporation of this kind of cyclical approach to the physics course enables pupils to form notions concerning the objective rigour and precision of the consequences of scientific theory and scientific foresight on the one hand, and of the existence of limits to the applicability of physical theory on the other. Within the school physics course, this approach is implemented in reference to classical mechanics, the molecular-kinetic theory of an ideal gas, and geometrical optics.

Problems of applied physics constitute an important component in the school physics course. It is largely this which explains the unequal time devoted to various topics within the course and the unequal distribution of the time devoted to their study. In particular, at the second-stage level, 33% of the time is devoted to mechanics, 13% to molecular physics together with specific subtopics in thermodynamics, 43% to electrodynamics (including optics taken together with the elements of the special theory of relativity, and 11% to quantum physics (including problems in nuclear physics). This distribution of study time reflects not only the pattern of study of physical theory in the school course, but also the relative significance of the subjects in question for the national economy and modern industry. In studying mechanics, for example, pupils become familiar with the physical fundamentals of the mechanization of production by studying such topics as the principle of action of an inclined plane, the screw, the water-driven turbine, the centrifuge, the aircraft wing and the jet engine. In studying electrodynamics, they become acquainted with such issues of applied physics as the principle of action and the uses of an electromagnetic relay, electrical measuring instruments, semiconductor devices, electrolysis, radar, television, lasers, optical instruments, etc.

Important changes are likewise being made in the content and methods of the school physics experiment. No longer does the latter serve simply to illustrate a lecture; increasingly it is becoming a means for the direct or indirect verification of hypotheses or theoretical conclusions. In other words, its role becomes analogous to that of its role in science. It is being used as a method for investigating various phenomena, as a basis for the formulation of hypotheses, and as a tool for the practical verification of theoretical conclusions and proposals.

Moreover, in connection with the growing importance of physics as a general educational subject, the requirements imposed on pupils as regards the acquisition of practical skills nd abilities are likewise being enhanced. The programme includes a list of practical skills which each pupil is called upon to develop. These include:

- the use of measuring instruments (slide calipers, micrometer, stop watch, hygrometer, ammeter, voltmeter, ohmmeter);

- the use of various instruments and devices (electric current rectifier, potentiometer, valve oscillator, transformer, radio receiver, microscope, photographic camera, spectroscope, photoelectric cell, Geiger counter).

Physics experiments constitute an integral part of the physics course. The programme incorporates 256 demonstration-type experiments, 47 teacher-performed ("Frontal") laboratory exercises, and 38 practical laboratory assignments. Thus, laboratory work accounts for 85 lessons, or nearly 16% of the total study time. This is much more than was the case prior to the modernization of Soviet secondary education undertaken towards the end of the 1960's.

Motion pictures are another important adjunct to the teaching of physics. The physics programme provides for the showing of 55 motion pictures on various programme topics. Table 3 indicates the number of demonstration experiments, films, laboratory exercises, and practical laboratory assignments.

TABLE 3

Grade	Experiments	Motion Picture Films	Laboratory Exercises	Physics workshop Assignments
VI	39	2	11	---
VII	48	3	14	---
VIII	37	15	8	10
IX	60	13	8	16
X	72	22	6	12
Total	256	55	47	38

A number of interesting trends may be noted in regard to the changing substance of laboratory exercises. On the basis of content, these can be broken down into five types, three of which are traditional:

- - Measurement of physical quantities (this helps to develop measurement skills and the ability to use instruments and evaluate measurement results);

- - performance of experiments underlying physical theories, i.e. of so called fundamental experiments such as the observation of Brownian motion, determination of the diameter of a molecule, and the production of electromagnetic induction (the number of such laboratory exercises has grown in recent years due to the increasingly higher scientific level of the school physics course);

- verification of the validity of physical laws entailing the validation of deductively derived theoretical consequences (such exercises not only facilitate mastery of physical theory, but are likewise of considerable importance for the shaping of a scientific world outlook, inasmuch as they equip pupils with the ability to implement scientific research methods while providing them with a tool for establishing the validity of an item of scientific knowledge).

The other two types of exercises are to a large extent novel. They require that the pupil either explain an unfamiliar phenomenon or obtain a specified physical-technical effect, i.e.:

- observation and investigation of physical processes and phenomena for the purpose of explaining them and establishing their patterns (such work serves to shape research skills, requiring the pupil to determine the aim of the work to be undertaken, to prepare a plan for its performance, to choose the necessary instruments and materials to carry out the required measurements, and to evaluate and interpret the results obtained);

- design and assembly of technical setups and arrangements, electrical circuits, and devices, coupled with the study of their operating principles, the recording of instrument characteristics, etc. (such work is particularly important from the standpoint of the polytechnical education of youngsters and the development of their abilities as designers).

Thus, the improvement of physics instruction in Soviet secondary schools may be said to be characterized by several cardinal features or trends:

- the increased role of physics as an integral component of general secondary edcation;

- enhancement of the stepwise structuring of the contents of the school physics course in line with the age-related capabilities of pupils, the aim here being the development of their cognitive powers;

- generalization of subject matter and contents on the basis of fundamental physical theories, i.e. classical mechanics, molecular physics with elements of thermodynamics, electrodynamics with certain information drawn from the special theory of relativity, and quantum physics;

- increased stress on the methodological side of the school physics course in order to promote the development of the pupils' intellectual capabilities and to instill a scientific world outlook;

- presentation within the school course of the theoretical foundations of the major current trends in engineering and technological advance: mechanisation, thermoelectric power, communications technology, automation, and nuclear and thermonuclear power production;

- the development of the cognitive and creative activity of young people and the reinforcement of practical skills through laboratory exercises.

Needless to say, these trends are not all entirely new, nor are they exclusive to Soviet schools. Nevertheless, they do constitute a substantially new stage in the development of general secondary education in Soviet Union.

2.2 The Development of Scientific Thinking in Pupils through the Study of Physics

The development of the methodology of physics instruction in the Soviet Union over the past fifteen years is characterized, first and foremost, by considerable success in establishing the ways that scientific thinking in pupils takes shape, in other words, of the ways in which a scientific world outlook develops. These ways have to do essentially with the equipping of pupils with necessary information concerning scientific method and with skills enabling them to use scientific method to cope with theories and solve practical problems. The development of scientific thinking in pupils studying physics is closely linked to an understanding of the relationship between theory and reality, i.e. with due consideration for the most important links in the cycle of scientific perception of the matters dealt with by physics. The sequence of these links in the development of science is as follows: the generalization of experimental facts in the language of physical concepts leads to the construction of an abstract model of the given real phenomenon and to the establishment of laws and principles to which that phenomenon is subject; the next step is the logical derivation of theoretical consequences or their experimental verification.

This, of course, does not mean that physics instruction in schools retraces the entire history of science. The contents of the school course are indeed based on fundamental theories, but it is simply not possible to divest the course of all elements of scientific method. The school course in physics simply has to be structured in accordance with scientific method, so that pupils come to recognize the significance of social practice as a source of perceptions, the role of abstract models and analogies in the process of gaining scientific insight, and the objective correctness of a given theory. Finally , the pupil must come to realize the importance of practice as a criterion for testing the truth of presumed knowledge.

A factor of paramount importance is the correct understanding by pupils of the relationship between phenomena studied and the theory underlying these phenomena. Two considerations are salient here. These are, first of all, the objective character of theory (concepts, laws, principles, theoretical conclusions), inasmuch as the latter is based on the generalization of experimental fact; second, it is the existence of limits to the applicability of a given theory, since all abstractions involves eliminating all that is not relevant. Understandably, something which is irrelevant under one set of circumstances becomes highly relevant in another context.

The existence of limits to the applicability of any physical theory is explained to pupils through the investigation of such concepts as that of a "material point", "mathematical pendulum"; "ideal gas", "crystal lattice", "absolute solid", etc. The symbolic representation of real objects is justifiable in certain instances, it stems from a generalization of observations and experimental data which yield theoretical solutions to various problems in accordance with practice and scientific experiment. The study of physics provides a good opportunity to demonstrate to pupils the considerable heuristic capabilities of physical theory. It is worthwhile, in particular, to systematically draw the attention of pupils to the fact that theory makes it possible to predict the course of events and that theoretical conclusions correspond to the results of physical experiments. By discussing examples of this relationship, teachers can enable pupils to gain a sound grasp of all of the components of physical science: observations, basic theoretical propositions, theoretical conclusions, and their correspondance to experimental results.

It is sound practice, when introducing physical concepts and laws, to accompany their presentation with an indication of their applications and the limits of their applicability, as well as to explain what it is that determines these limits. Thus, classical mechanics is not applicable to the notion of bodies moving at very high velocities, i.e., velocities close to the speed of light. On the other hand, such

motion is correctly describable in terms of the special theory of relativity. The model of an ideal gas affords a faithful representation of the properties of real gases at high temperatures and low pressure; Coulomb's law and the law of universal gravitation are applicable to the calculation of energy level for single-electron systems only, etc. It is recommended, however, that these points be explained to pupils from the standpoint of materialistic dialectics. In other words, it is advisable to talk about the relativity of all human knowledge not in the sence of its negating objective truth, but rather in terms of the historical contingency of the limits of approximation of this truth in terms of current knowledge.

The physics course is structured in such a way as to convey to the pupil a notion of each fundamental theory as a whole, as well as of the relationships between fundamental theories.

For example, mechanics is the science concerned with the mechanical motion and interaction of macroscopic bodies whose velocity is much less than the speed of light.

The consideration of the motion and interaction of bodies in theoretical mechanics involves an idealization, i.e. emphasis on what is relevant and excision of that which is irrelevant:

- reference is made not to bodies, but rather to material points;

- it is assumed that there exists a fixed space whose properties do not vary as bodies move through it;

- it is assumed that there exists time whose passage is absolutely uniform;

- reference is made to the existence of inertial coordinate systems in which Newton's First Law holds.

Mechanics relies on a number of scientific concepts which characterize the properties of bodies, their motion, and their interaction, e.g.: mechanical motion, the notions of a material point, coordinate systems, time of travel, path, displacement, velocity, acceleration, inertia, mass, force, momentum, mechanical work, and potential and kinetic energy.

A central role in the overall concept is played by laws in accordance with which mechanical interactions occur in nature.

These include the three laws of Newton which express the character of changes in the motion of a body as determined by the force or forces acting upon it and by the inertial properties of the body.

Another example are the laws expressing the relationship between forces of differing physical nature on the coordinates and velocity of a body (the law of universal gravitation, Hooke's law, the laws which enable us to determine the magnitude of a friction force).

Finally, they include the laws of conservation of momentum and energy.

Classical mechanics makes it possible to solve various practical problems. It is this discipline which is the basis of the mechanisation and automation of production, machine building, transportation, civil and mining engineering, rocket technology, and space travel.

Mechanics is applicable within certain limits only. The motion of bodies travelling at velocities close to those of light is described by the theory of relativity. The motion and interaction of microobjects is the domain of quantum mechanics.

Similar theoretical generalizations are adduced in covering other fundamental theories.

Molecular physics is concerned with the regularities of motion, of large aggregates of molecules and atoms. It is based on the fact that large systems of particles exhibit certain general statistical regularities. These general regularities or patterns do not require knowledge of the character of motion of the individual particles constituting the system. What is required is a knowledge of average quantities only, such as the average distance between particles, the mean pressure, the mean-square of the velocity, etc. Statistical regularities interrelate the average quantities characterizing the motion of microobjects with macroscopic parameters, characterizing the system as a whole, such as volume, pressure, temperature, internal energy, etc.

Electrodynamics, together with the elements of the special theory of relativity, deals with the notions of point charges (charge bodies) and of a continuous elecromagnetic field with which these charges interact. The interaction of charged bodies is mediated or transmitted by the field at a finite velocity (i.e., the velocity of light).

Quantum physics is concerned with the interaction of microobjects. One of the salient features of quantum physics is that it deals with its objects in a discrete manner. In particular, light is emitted by atoms, propagates, and is absorbed by atoms in the form of quanta known as photons. The interaction of microobjects occurs through the emission or absorbtion of energy quanta. Changes in the energy of microobjects occur in jumps.

The attention of pupils is drawn to the fact that many physical notions reflect the particularities in the form of motion of matter in a specified way. For example, interaction in mechanics is characterized by force. In quantum physics, the notion of force becomes meaningless. On the other hand, such notions as energy and momentum have universal significance, remaining useful within all physical theories. The existence of such universal notions points to the material unity of the world.

Thus, the task of the teacher in presenting physical theory is essentially one of demonstrating that physical concepts are the result of the reflection of the most salient features of the world around us, and that they are characterized by varying degrees of generality and differing domains and limits of applicability.

To be specific, the contents of the present-day school course in physics broken down according to basic categories of theoretical generalization may be set out as follows:-

MECHANICS

Facts: Galileo's experiments, the free fall of bodies with uniform acceleration, the variation of the velocity of interacting bodies, etc.

Basic concepts: Mechanical motion, inertial coordinate systems, a material point, trajectory, translational motion, path, velocity, acceleration, inertia, mass, force, momentum, work, kinetic energy, potential energy, power.

The idealized model of mechanical phenomena: Under certain conditions interacting bodies can be represented as material points; the action of each body on any other is instantaneous.

Laws: The First, Second and Third laws of dynamics, the laws of conservation of momentum and energy, the law of universal gravitation, Hooke's law, the dependence of the friction force on velocity.

The implications of theory and their practical applications:
The motion of bodies acted on by one or more forces (gravity, elastic forces, friction); the free fall of bodies; the fall of bodies in gases and liquids; the oscillatory motion of a pendulum; motion in transportation; the motion of rockets, planets and artificial earth satellites; the equilibrium of bodies; the efficiency of mechanisms; the physical foundations of the mechanization of production processes.

MOLECULAR PHYSICS
THE FUNDAMENTALS OF MOLECULAR-KINETIC THEORY

Facts: Brownian motion, the Stern-Gerlach experiment, diffusion, the mass and size of molecules.

Concepts: Temperature, pressure, volume, mean-square velocity of molecules.

The model of an ideal gas: A gas consists of material points which move in a chaotic manner, interacting as elastic balls upon collision and not interacting over distances.

Laws: The basic equation of the molecular-kinetic theory of an ideal gas; the equation of state of an ideal gas.

Implications of theory and their practical applications:
The particular cases of the equation of state of a gas where one of the parameters (temperature, volume, pressure) is constant; the practical applications of these cases in engineering.

THERMAL EFFECTS. THE FIRST LAW OF THERMODYNAMICS

Facts: The equivalence in terms of energy of the amount of heat and the amount of work.

The model of thermal phenomena: The internal energy of a body varies when the body performs work and/or by heat transfer.

Concepts: Temperature, pressure, volume, work, internal energy, adiabatic processes.

Laws: The First Law of Thermodynamics

Implications of theory and their practical applications:

The efficiency of heat engines and ways in which it can be increased.

ELECTRODYNAMICS

Facts: Electrization, Electrical interaction, the existence of elementary charges, the limiting velocity of propagation of light and radio waves, the spectra of electrostatic and magnetic fields, free carriers of charges in conductors, the polarization of dialectrics, the phenomenon of electrolysis, the magnetic interaction of bodies, the experiments of Hertz, the rectilinear propagation of light, the colours of thin films, interference, diffraction.

Concepts: Short range interaction, the electrical charge, the electromagnetic field, field strength and field potential, electrical current, voltage, current strength, the resistance of a conductor, the Lorentz force, electromagnetic induction, magnetic flux, dialectric permeability, magnetic permeability.

Model: Matter exists not only in the form of charged bodies (material points), but also in the form of fields; each point in a field has a particular energy and force value; a field acts on charged bodies in a direct way (short-range interaction); the propagation of a field in a vacuum proceeds with a finite constant velocity; an electric field surrounds a charge which is at rest; variations in an electric field are accompanied by the induction of a magnetic field and vice versa; a vortical electromagnetic field can exist independently of charged bodies.

Laws: Conservation of charge, Coulomb's, Ohm's and Ampere's laws, the law of electromagnetic induction, illuminance, reflection and refraction of light.

Implications of theory and their practical applications:

Production, transmission and use of electrical energy, vacuum and semiconductor devices, electrolysis, optical instruments.

SPECIAL THEORY OF RELATIVITY

Facts: The Michelson-Morley experiment.

Concepts: The relativity of simultaneity, time intervals and distance.

The model of space, time and interaction: Absolute space and time and "privileged" coordinate systems do not exist; the principle of relativity extends to electromagnetic phenomena.

Principles: 1) Einsteinian relativity; 2) the constancy of the speed of light in vacuum for all inertial coordinate systems.

Implications of theory and their practical applications

The relativistic formula for the addition of velocities, the dependence of mass on velocity; the relationship between mass and energy; the use of relativistic effects in accelerators; nuclear energy.

QUANTUM PHYSICS

Facts: The existence of thermal equilibrium in nature, the dependence of photoelectron energy on light frequency and its non-dependence on light intensity; diffraction of photons and electrons.

Concepts: Planck's constant, quanta, photons, quantum emission, absorption of light by atoms.

The model of the structure of matter and fields and matter-field interaction: Light (electromagnetic waves) has a discontinuous structure; it is emitted and absorbed by atoms of matter in discrete portions known as quanta; the corpuscle-wave dichotomy of the properties of light and microobjects (electrons).

Laws: The law of the photoelectric effect; Bohr's postulates.

Implications of theory and their practical applications:
Aspects of the structure and interaction of atoms; the applications of the photoelectric effect; quantum light sources; properties of elementary particles.

The contents of demonstration experiments tend to vary in accordance with the corresponding stage in the physics teaching cycle (we recall that the pupil passes from facts to theory and from theory to practice). In other words they can be used to support with illustrations the basic factual knowledge underlying a given theory, or else as an easy-to-understand expression of model hypotheses; finally, they can serve as a means of verifying theoretical conclusions or illustrating the practical applications of science to industry and agriculture. For example, in Grade VI the study of the topic "Liquid and gas pressure" includes the following demonstration experiments:

- transmission of pressure by liquids and gases;

- pressure exerted by a liquid against the bottom and walls of a vessel;

- the discovery of atmospheric presure;

- pressure measurements;

- the underlying principles of mercury and aneroid barometers;

- communicating vessels;

- the design and mode of operation of a hydraulic press.

In working through the topic "Fundamentals of molecular-kinetic theory" in Grade IX, pupils are offered demonstrations of phenomena such as:-

- diffusion of a gas through a porous partition;

- dependence of the pressure of a gas on volume at constant temperature.

In addition, they are shown mechanical models simulating

- Brownian motion;

- gas pressure;

- the Stern-Gerlach experiment.

The laboratory exercises performed before the class and in the physics workshops can be broken down into the following groups:

- observation of phenomena and processes (boiling, Brownian motion, interaction between a magnet and a current, electromagnetic induction, interference of light, diffraction, dispersion; etc.);

- graduation of instruments (dynamometer, spectroscope);

- measurement of physical quantities characterizing the properties of matter and radiation (specific resistance, index of refraction, background radiation, etc.)

- familiarization with physical laws (conservation of energy when potential energy is transformed into kinetic energy, the equation of the gaseous state);

- determination of certain physical constants (free-fall acceleration, the rigidity of a spring, the coefficient of friction, the specific resistance of a conductor, the index of refraction of glass);

- assembly of very simple devices and parts of engineering instruments (electromagnet, relay, models of an electrical motor and a transformer, radio receiver, microscope);

- study of the characteristics of devices (electronic valve, semi-conductor, motor).

The system of experimental methods used in the school physics course includes the following: direct evaluation (e.g. the measurement of temperature by means of a thermometer), substitution (measurement of resistances and capacitances), coincidence (e.g., recording of motion by means of a chronometer), compensation (the use of bridge circuits). Oscillagraphic, calorimetric, spectroscopic and other instrumental methods of investigation are likewise employed.

The cyclical approach to the coverage of subject matter can be illustrated by describing the presentation of a specific subject such as the equation of state of an ideal gas (Figure 2.1).

Basic facts: The molecular-kinetic theory of gases is based on a body of factual knowledge built up by observing various phenomena and by performing experiments.

A gas fills up the entire volume of the vessel in which it is contained. Its volume can vary over extremely wide limits, i.e. a gas can expand and contract. What happens when different gases are combined is that they interpenetrate one another, a phenomenon known as "diffusion". A very convincing way of showing this is to demonstrate the diffusion of bromine and air vapours:

A drop of bromine is introduced into a glass cylinder. It evaporates rapidly. The heavier, brown-coloured bromine vapour is initially seen to be confined to the lower part of the cylinder. This is followed by the gradual spontaneous penetration of the bromine vapours into the air and vice versa.

The model/hypothesis: The foregoing facts enable us to construct an idealized model of a gas. Let us imagine that a gas consists of tiny elastic balls/molecules in continuous chaotic motion.

Such a model of a gas enables us to explain the existence of gas pressure as the total momentum conveyed by the molecules to a unit area of a body per second. If the gas is confined in a vessel, then, knowing the number N molecules contained in it, the volume V of the vessel, the mass of a single molecule m as well as the mean velocity of motion of the molecules v, we can calculate the gas pressure P exerted on the walls of the vessel:

$$p = \frac{2}{3} \frac{N}{V} \cdot \frac{mv^2}{2}$$

Theoretical implications: One of the important logical consequences of the above hypothesis is Boyle's (Mariotte's) law, namely

$$pV = \frac{2}{3} N \frac{mv^2}{2}$$

Experimental verification: This logical conclusion concerning the inverse proportionality of gas pressure and volume at constant temperature is readily verifiable by means of a demonstration experiment. For example, by reducing the volume of a gas by a factor of two we increase its pressure by the same factor.

In shaping a scientific world outlook it is essential to demonstrate not only the interrelation of experimental facts, concepts, models, laws, principles and experiments within each fundamental theory, but also the interrelation among fundamental theories themselves. Hence, the programme incorporates a special general lesson on the subject "The modern physical picture of the world". In mastering this lesson, pupils learn that any new and more general physical theory by no means negates an older theory, but rather incorporates the latter as a particular case. In other words, pupils become familiar with the correspondence principle of Niels Bohr in its more accessible form. In accordance with this principle, any new theory in physics must be reducible to a well known corresponding classical theory in those cases which are describable by means of this less general classical theory.

2.3. The Polytechnical Education and Practical Training of Pupils through the Study of Physics

The teaching of all general educational subjects in Soviet schools is structured in accordance with the principles of polytechnicity. This means that school courses are concerned, not simply with pure science, but also with the most important practical applications of science. The school is supposed to equip the young person not only with a knowledge of science fundamentals, but also with a familiarity with the basics of modern industry in theory and in practice. The fulfillment of this task is insured by the inclusion in the course material of issues of applied physics illustrating in the most accessible way the possibility of making practical use of scientific knowledge for the development of the national economy.

In specific terms, the following examples of applied physics and illustrations drawn from the appropriate textbooks can be cited in connection with various grade levels and topics:

Grade VI. Gauges. The hydraulic press. Pumps. The conditions under which bodies float. Water transportation. Aeronautics and aerostatics. The efficiency of mechanisms. (Figure 2.2).

Grade VII. River and wind energy. Energy conversion in heat engines. The internal combustion engine. The steam turbine. The series and parallel connection of conductors. Electrical heaters. The short circuit. Fuses. The electromagnet. The telephone. The microphone. The DC motor. The generator. (Figure 2.3).

Grade VIII. The motion of bodies acted on by elastic forces and gravity. The weight of an accelerating body. Weightlessness. Overloads. The motion of artificial earth satellines. The calculation of circular (orbital) velocity. The motion of a body acted on by a friction force; motion under the action of several forces. The principle of action of centrifugal mechanisms. The equilibrium of bodies. Center of gravity. Stability of bodies. Jet propulsion. The lifting force (lift) acting on an aircraft wing. (Figure 2.4).

Grade IX. The principle of action of thermal engines. The maximum efficiency of a thermal engine.

Crystalline bodies. The anisotrophy of crystals. Defects in crystals. Polycrystals. Amorphous bodies. The mechanical properties of solids and materials; elasticity, strength, plasticity, brittleness.

The use of electrolysis in engineering. The engineering uses of discharge in a gas. The use of semiconductor instruments. The engineering applications of ferromagnetic materials. The principles of operation of electrical measuring instruments (Figure 2.5).

Grade X. Resonance and allowance for it in engineering. Autooscillations as illustrated by the pendulum clock. The valve oscillator.

The AC oscillator. The transformer.

The transmission and use of electrical energy in industry, transportation and agriculture.

Accoustic resonance. Ultrasonics and it application.

The principles of radiotelephony. A simple radio receiver. Optical instruments. X - radiation and its applications. The chemical action of light and its uses. The energy yield of nuclear reactions. The nuclear reactor. The thermonuclear reaction (Figure 2.7).

In order to increase the effectiveness of polytechnical education, it is recommended that teachers systematize their presentation of topics in applied physics in accordance with the principal orientations of progress in science and technology on the basis of the physical theory under consideration. In particular, the following comparisons can be proposed: the mechanics and the mechanization of production; molecular physics and thermal power generation; electrodynamics and electrical power production; quantum physics and applied physical optics and nuclear physics. These orientations subsume all of the particular problems of applied physics which enter into the present-day physics curriculum, making it possible to generalize the presentation of course material while stressing that which is most important in it.

In specific terms, the mechanization of production includes such particular issues covered within the school physics course as the use of river and wind energy, gauges, the hydraulic press, pumps, transmission mechanisms, machines, land, water and air transportation and spacecraft.

Thermal power production covers such isues of applied physics as the principle of operation of thermal engines, their uses at electrical power stations, in transportation and in agriculture, and in military engineering.

The production of materials with specified properties covers any number of issues in the treatment and handling of materials, e.g., rolling, stamping, forging, etc.

Electrical power production relates to such issues of applied physics as electrical measuring instruments, superconductivity, electrolysis, electronic and ionic instruments, semiconductor instruments, electrical generators and motors, transformers, capacitors, the principle of radiotelephony, radar and television.

Radioelectronics includes information concerning elements of radio transmission, radio reception and radar.

Applied physical optics covers optical instruments, lasers and nuclear and thermonuclear reactions.

Nuclear power production encompasses the principle of action of an atomic electrical power station and the use of isotopes in medicine and in agriculture.

Units relating to the automation of production include information concerning automatic control and automatic regulation of industrial processes.

The contents of the school physics course offer ample opportunity for relating physics studies to everyday experience in industry, offering an excellent opportunity for pupils to develop an unflagging interest in the subject matter.

The school physics programme provides for general lessons on the following topics:

- the mechanics and mechanization of production (grade VIII);
- the basic laws of electrodynamics and their engineering applications;
- advances in and prospects for the electrification of the USSR (grade X);
- development of communications in the USSR (grade X);
- physics and the revolution in science and technology (grade X).

The system of presenting issues in applied physics as integral components of fundamental physical theory is set out in Table 2.1 below.

TABLE 2.1

Physics Course Sections and Topics	Grade	Orientation of scientific and technological progress (or field of engineering)	Industry and/or types of machines	Specific types of engineering device, tool, instrument, etc. (Examples)
1	2	3	4	5
1) Mechanics	VI VII	Mechanisation of production and agriculture	Mechanisms, machines, transportation, civil engineering, agricultural technology	Lathe, drill press, milling machine, automobile, aircraft, tractor, locomotive, steamboat, lifting crane, jack, plow, cultivator, combine harvestor.
2) Thermal Effects	VII IX	Thermal power production	Thermal engines	The internal combustion engine, the steam turbine.
3) Molecular Physics	VII IX	Production of materials with properties	Technology of materials treatment and handling	Springs, rubber and plastic gaskets, cutting of materials rolling, stamping, pressing cold-working.
4) Fundamentals of electrodynamics	VII IX, X	Electrical power production	The use of electrical energy	The incandescent lamp, electromagnet, telegraph, electromagnetic relay, telephone, electrical motor, electrolysis in industry.
			Electrical power production	The electrical power station the generator.
			Transmission of electrical power	The electrical power transmission line, the transformer
5) Electromagnetic waves	X	Radio electronics	Radio transmission, radio reception, radar reception, radar	The radio station, radio receiver, television set, radar equipment.

6) Optics	X	Instrument and equipment design	Lamps, optical instruments, optical sensors, photosensitive materials, lasers	The photographic camera, spectacles (glasses), lenses, the microscope, projectors, the incandescent tube, photo-cells, photographic film and photographic paper, X-ray tubes, infrared and ultra-violet instruments lasers.
7) Physics of atom and of the atomic nucleus	X	Nuclear power production	Atomic electrical power stations, the use radioactive isotopes in industry, agriculture and medicine	Nuclear reactors, radio active isotopes dosimeters
8) All sections	All Grades	Automation of Production	Automatic control	Sensors, relays, amplifiers actuators
			Automatic regulation and control	Closed and open automata.

As will be seen from the above table, the treatment of production automation within the context of the school physics course is different from the approach taken in regard to other scientific and engineering applications. The distinctiveness of the issue in question has to do with the fact that the theme of automation permeates the entirety of the subject matter: the pupil receives his first information concerning automata in grade VI; in grade VII, he learns about programme control and sensors when studying electrical circuits and telephony; in grade VII, his study of a centrifugal controller gives an opportunity to understand automatic control involving feedback; in grade IX, his knowledge of sensors of various physical types is extended; in grade X additional information is provided concerning programme control, feedback and sensors. The system of covering this material is set out schematically in Table 2.2.

TABLE 2.2

Grade	Studies in the principal forms of automation	Basic Concepts	Topics within the physics course
VI	Automatic control	Basic information concerning automata and sensors; block diagram of an automatic control device.	Introduction, gas pressure, floating of bodies.
VII	Programme control	Programme and programme control; rheostatic and carbon sensors; relays.	The electrical circuit and its component elements, rheostats, electromagnetic relays.
VIII	Automatic control with feedback	The concept of feedback; basic components of automatic devices with feedback.	Natural forces; the application of the laws of motion.
IX	Further information concerning automatic regulation and control	Sensors: Capacitor, thermistor and photo-resistor types; relay-type control circuits temperature controls; memories	Thermal expansion of solids, electrical capacitance of a plane condensor, super-conductivity, thermistors and photo-resistors, magnetic properties of matter.
X	Further information concerning all forms of automation.	Programming methods; block diagram of a programme control automation.	The role of the pendulum in a clock, the autooscillator, the valve oscillator, amplitude modulation, demodulation, the photoelectric effect, the synchrophasotron, the nuclear reactor, physics and the scientific-technological revolution.

Why are various topics in engineering and technology taken up within the physics course? What is their role within the physics programme?

First of all, their important independent role cannot be doubted. The principles underlying the functioning of an electric motor, generator, transformer, photographic camera, etc. must be familiar to every educated person. They are essential components not only of practical activity, but also of general intellectual development. However, this does not exhaust the significance of applied-science material within the school physics course. A partial list of the important educational and training tasks dealt with by applying theortical knowledge to engineering equipment and technological processes within the physics course would run as follows:

- deepening of pupils' knowledge;
- development of the ability to apply knowledge to practical ends;
- development of an interest in a given subject and motivation to learn;
- development of creative abilities.

Let us consider just one of the items in the above list.

Schools are called upon not simply to provide knowledge concerning the fundamental principles of modern industrial production, but also to equip pupils with the ability to apply theoretical knowledge in practice. Broken down by grades, the progression is as follows:

Grade VI

- practical application of knowledge concerning physical effects and regularities: diffusion in liquids and gases; differences between the densities of substances; floating of bodies; pressures in liquids and gases; Pascal's law; the buoyancy force; inertia; friction;

- explanation of the workings and use of the following measuring instruments: glass measuring vessels, scales and balances, the dynamometer, the barometer;

- solution of problems involving the above effects and regularities.

Grade VII

- to explain the following on the basis of molecular-kinetic and electron theory: thermal motion, changes in internal energy accompanying changes in the temperature of a body, convection, thermal conductivity, floating of bodies, evaporation of liquids, cooling of a liquid as it evaporates, changes in the aggregate state of matter, electrization, electrical currents in metals and electrolytes, electrical resistance, heating of a conductor by an electric current;

- solution of problems involving the above regularities.

Grade VIII

- solution of problems involving the application of Newton's laws, the laws of conservation of momentum and energy, and the conditions of equilibrium of a body;

- carrying out measurements and very simple calculations involving the determination of the coordinates of a body, velocity, acceleration, path length and displacement, mass, force, momentum, work and energy;

- use of the following instruments: beam compass, straight-edge ruler, protractor.

Grade IX

- reading and plotting graphs of functions relating the basic parameters of the state of a gas (pressure, temperature, volume);

- solution of problems involving: the basic equation of the molecular-kinetic theory of gases, the Mendeleev-Clapeyron equation, the formula relating the absolute temperature of a gas to the average kinetic energy of its molecules, the first law of thermodynamics, the efficiency of thermal engines, air humidity, Coulomb's law and the law of conservation of charge, Ohm's law for a closed circuit, the law of electrolysis, the calculation of field strength and voltage, electrical capacity, work and power of a current, magnetic induction, the inductive electromative force and the forces acting on a current-carrying conductor and on charges moving through an electric field;

- the use of the following measuring instruments: barometer, thermometer, pressure gauge, psychrometer, hygrometer, ammeter, voltmeter, ohmmeter;

- use of the electric current rectifier and slide wire;

- construction of graphs on the basis of experimental data (the voltage-current curve of a diode; the temperature curve of a thermistor).

Grade X

- reading and plotting of graphs (of harmonic oscillations, of photocurrent as a function of voltage, of radioactivity of a substance as a function of time);

- theoretical explanation of phenomena such as the damping of free oscillations, resonance, interference and diffraction of waves, the photoelectric effect, the line spectra of emission and absorption;

- the use of instruments and familiarization with the principles of their operation (the clockwork, the valve oscillator, the AC generator, the transformer, a simple radio receiver, the microscope, the spectroscope, the photoelectric cell, the Geiger counter);

- solving problems using formulas to find the following: the period of oscillations of a mathematical pendulum and oscillating circuit; the law of conservation of energy in oscillating mechanical and electromagnetic systems; the relationship between the velocity of wave propagation on the one hand, and wavelength and frequency on the other; the laws of geometrical optics; the relationship between mass and energy; Einstein's equation for the photoelectric effect; the equations of nuclear reactions;

- experimental determination of the following: the refractive index of materials; the focal length of a lens; the length of a light wave.

Such practical skills and abilities are developed in pupils by way of demonstration experiments and in the course of carrying out laboratory exercises. Particularly important matters are coverd by such front-of-classroom demonstrations and practical exercises as those entitled "Measuring mass by means of a balance", "Determining the density of a solid", "Graduated springs and measuring forces by means of a dynamometer", "Measuring friction", "Investigating the conditions under which a body will float in a fluid", "Investigating the conditions of equilibrium of a lever", "Determining the efficiency of an inclined plane in lifting a body" (grade VI); "Studying the purpose and the design of a calorimeter and thermometer", "Assembling an electrical circuit and measuring the current at various points within it", "Determining the resistance of a conductor using an ammeter and voltmeter", "Determining the strength of a current consumed by an electrical valve (tube)", "Determining the efficiency of an electrical heating device" (grade VII); "Determining the rigidity of a spring", "Determining the coefficient of sliding friction", "Investigating the motion of a horizontally thrown body", "Determining the centre of gravity of a body", "Determining the velocity of a projectile using a ballistic pendulum" (grade VIII); "Determining the coefficient of surface tension".

"Determining the electromotive force and internal resistance of a current source", "Determining the specific resistance of a conductor", "Determining the electrical capacity of a condenser", "Recording the voltage-current characteristic of a semi-conductor diode" (grade IX); "Determining the principal focal length and optical strength of a collecting lens", "The recording and reproduction of sound", "Transformer design and operation", "Assembling a model radio receiver", "Studying the photographic camera and the process of photography" etc. (grade X).

For many pupils such laboratory exercises serve as a stimulus for becoming involved in further interesting work in an informal special- interest circle or at home, encouraging them to build their own engineering devices and models. A list of pupil assignments linked to various topics in the physics course (Table 2.3) is certainly useful in organizing such work. The table in question also contains a list references useful to both teachers and pupils.

TABLE 2.3
A LIST OF POSSIBLE ASSIGNMENTS INVOLVING THE CONSTRUCTION OF ENGINEERING MODELS

Assignment	Reference
1	2
MECHANICS	
Device for the graphic recording of linear oscillatory motion.	Razumovskii, V. G., Razvitie tvorcheskikh sposobnostei uchashchikhsya v protsesse obucheniya fizike (Developing the Creative Faculties of Pupils Through the Study of Physics) Moscow, Prosveshchenie, 1975.
A model automobile which moves with a prescribed acceleration.	ibid.
The accelremeter	Fizika v shkole, No. 4, 1972
A model lifting crane	Bilimovich, B.F., Zakony mekhaniki v tekhnike (The laws of mechanics in engineering). Moscow, Prosveshchenie, 1975.
A model tower crane	ibid.
A model gantry crane	ibid.

1	2
A model flax puller	ibid.
A model jet turbine	ibid.
A model hovercraft	ibid.
A model for studying weightlessnes	Yunyi tekhnik, No. 12, 1971
A model of the Foucault pendulum	ibid.
A model of the "Soyuz" spacecraft	Yunyi tekhnik, No. 9, 1975
A model orthopter	ibid.
A torsion balane	Yunyi technik, No. 2, 1971
ELECTRODYNAMICS	
A model synchrophasotron	Yunyi technik, No. 1, 1971
A welding set	Yunyi technik, No. 9, 1971
A model magnetic suspension for an ultracentrifuge	Yunyi technik, No. 11, 1971
A model seismograph	Yunyi technik, No. 2, 1971
OPTICS, ATOMIC PHYSICS	
A photometer	Pokrovskii, A. A. (ed.) Demonstratsionnyi eksperiment po Fizike v srednei shkole (The Demonstration Experiment in the Secondary School Physics Course) Part 2, Moscow, Prosveshchenie, 1979, p. 155.
A burner for obtaining a sodium-vapour-coloured flame	ibid. p. 218
A model periscope	Yunyi technik, No. 9, 1971
A KYuT-1 model laser	Modelist-konstruktor, No. 7, 1970
A mirror telephone	Yunyi technik, No. 10, 1971
An infrared radiation sensor	Kvant, No. 5, 1973
A model telescope	Yunyi tekhnik, No. 11, 1971

A model microscope	Yunyi tecknik, No. 11, 1975
A home-made telescope	Yunyi tecknik, No. 6, 1974

RADIO ENGINEERING AND AUTOMATION

A take-apart and put-together semiconductor oscillograph	Yunyi tekhnik, No. 11, 1970
A radiotelephone	Yunyi tekhnik, No. 6, 1970
An electronic counter	Yunyi tekhnik, No. 1, 1970
A UHF reeiver	Yunyi tekhnik, No. 9, 1971
An electronic thermometer	Yunyi tekhnik, No. 4, 1971
A ten-number walkie-talkie	Yunyi tekhnik, No. 3, 1971
An electronically controlled skimming boat	Yunyi tekhnik, No. 8, 1971
A jet aeroplane	Yunyi tekhnik, No. 10, 1971
A model adding machine	Razumovski, V.G., Razvitie tvorcheskikh sposobnostei, uchashchikhsya v protsesse obucheniya fizike (Developing the Creative Faculties of Pupils Through the Study of Physics) Moscow, Prosveshchenie, 1975
A handy instrument for the plant and animal breeder	Yunyi tekhnik, No. 1, 1971
A humidity indicator	Ibid.
An incubator	Yunyi tekhnik, No. 2, 1970

2.4. The development of creative abilities through the study of physics

One of the most topical tasks of physics instruction in Soviet secondary schools today is that of improving the quality of the knowledge acquired by pupils while at the same time developing their creative abilities. This is important not simply because the subject happens to be physics, which is still the spearhead of scientific and technological progress in today's world: another highly relevant consideration is that creativity in study and work quite simply makes school-age youngsters happier. Coping successfully with the task of encouraging the development of creative faculties in pupils as they go about studying physics is closely related to the task of raising the scientific level of the content of the physics course, and, more specifically, to the fact that the latter now incorporates issues of scientific method i.e. of the techniques used by scientists to investigate physical phenmena. What is meant here is the interrelation of real (natural) objects and phenomena on the one hand and an idealized model on the other; the theoretical derivation of implications and their experimental verification; intuitive deducation ("educated guessing") and the derivation of rigorous logical conclusions from a given model of a phenomenon and from established laws recognized as applicable to that phenomenon.

The way in which the creative activity of physics pupils may be organized is best described by considering the process of scientific creation itself.

As early a thinker as Galileo saw this process as consisting of four phases:

- a sensory experiment which yields facts;
- intuitive transition to a hypothesis;
- the formulation of logical implications;
- the experimental verification of such implications (Figure 2.8).

It should be noted that transitions from one particular phase of the creative process to the next are not equivalent from the standpoint of mental activity. This was understood very clearly by Einstein, who in one of his letters (dated May 7, 1952) illustrated his thinking by means of a diagram (Figure 2.9): let us say that

E are data obtained directly from sensory experience (facts);

A are the axioms (hypotheses) from which implications are logically derived.

We note, however, that there is no direct logical relationship between E and A, the connection between them being intuitive or psychological.

Thus, rigorous scientific deduction and proof are harmoniously complemented by intuition and "educated guessing" (conjecture, surmise).

Intuitive conjecture is subjectively linked with emotional status, i.e. with feelings of happiness or frustration. This means that a teacher who organizes the learning process in such a way that his pupils make discoveries which they themselves could not have expected and are able to find ways of verifying the correctness of the newly-discovered solution makes learning not only an engrossing, but quite simply a joyous experience. On the other hand, at lessons where strict logical derivation and rote memorization are the rule, no room is left for creative questing, error, failure and, in the final analysis, conjecture, which means, quite simply, that the pupils experience neither joy nor satisfaction.

Needless to say, where teaching methods are lopsided, the aptitudes and abilities of pupils tend to develop in a lopsided way as well. Quite often pupils will exhibit a greater ability for memorization and for drawing logical conclusions than for creative (intuited) results. In such instances, if a pupil is apt to perform three types of assignments covering the same study material, namely that of

- defining a concept or formulation a law,

- solving a simple logical problem,

- applying newly-acquired knowledge to new conditions and "intuiting" something on the basis of that new knowledge, it turns out that the first assignment will be perceived as the simplest and the third as the most complex and/or difficult. Indeed, this is probably as it should be, yet differences in coping successfully with such class assignments ought not to be overly great. According to the results of our research, they should not exceed 10%.

Teachers in Soviet schools employ various instruction techniques to compensate for lags in pupil creativity. Such techniques include the assignment of creativity-centered problems and laboratory exercises, as well as assignments in design which require that the pupil exhibit not only an ability to draw logical conclusions, but also to think intuitively and to verify ideas both in theory and in practice.

All such means of encouraging pupil creativity are employed by teachers in various forms, i.e., in lessons, as part of homework, as well as a component of out-of-class work in special interest groups for pupils who display particular curiosity for science and engineering.

ASSIGNMENTS

ASSIGNMENT 1

A checker-shaped piece (puck) is placed at the edge of a horizontal turntable. Gradually the turntable begins to move and speed up. At a given instant the puck slides off the turntable (Figure 2.10).

Explain what happens. Why, and under what conditions, does the puck slide off the turntable?

SOLUTION

At first the puck moves along a circular orbit, acted on by the force of friction. At a certain angular velocity this force reaches its maximum value. As the angular velocity of the turntable increases still further, this force is no longer insufficient to retain the puck, which shoots off the turntable at a tangent to the circumference of the turntable.

This solution can be verified experimentally by measuring the friction force and computing the limiting velocity of rotation of the turntable.

The same method can be used to determine the coefficient of friction. This can be done simply by measuring the mass of the puck.

ASSIGNMENT 2

Design a pair of pliers which would have a "bite" several times greater than ordinary pliers with handles and jaws of the same length.

SOLUTION

One possible solution is shown in Figure 2.11. Such pliers make use of the principle of the lever.

ASSIGNMENT 3

The assembly of certain mechanisms involves a high degree of precision in the tightening of bolts: when too little force is applied, the bolt is not tightened sufficiently, whereas the application of excessive force can result in the inelastic straining of the bolt and stripping of its thread. Design a wrench which would make it possible to tighten nuts and bolts with a specified torque.

SOLUTION

A schematic drawing of such a wrench is shown in Figure 2.12. The torque is regulated by means of a spring which is fully stretched once a given force is applied, whereupon further tightening of the bolt ceases.

The ability of pupils to apply their knowledge in creative ways can be successfully tested by means of multiple-choice problems such as the following: the bar of a friction gauge must be made to move at a specified constant velocity. Which of the devices shown in Figure 2.13 is suitable for this purpose - A, B, C, D or E (the correct answer is E).

Other methods suitable for enhancing the creative abilities of pupils include the following:

- experimental problems set up by the teacher in the form of experiments on the demonstration table;

- laboratory exerises performed by pupils as part of their classroom work;

- laboratory exercises performed by pupils as part of their homework, using household articles and materials;

- assignments involving the design and building of various models (such models usually require quite a bit of time to execute and are usually made by students as part of special-interest circle activities or leisure activities at home).

What follows is a list of creative home laboratory experiments in mechanics and several design exercises whose execution does not require special equipment.

LABORATORY EXERCISES WHICH CAN BE CARRIED OUT AT HOME

(Texts of assignments handed out to pupils and possible solutions)

UNIFORM AND ACCELERATED MOTION

The validity of many physical laws can be demonstrated by means of very simple experiments which can be performed by the pupil himself without the aid of any complex devices or equipment. For example, using a ruler and a homemade pendulum, the pupil can observe two forms of rectilinear motion, namely, uniform and accelerated motion. The role of the pendulum in these experiments is that of a time-keeping device. The most convenient length of pendulum thread is 25-35 cm; the pendulum weight can be a thimble-sized piece of plasticene.

A pendulum is a more convenient means of measuring time than is the second hand of a watch in such experiments, since it enables the pupil to keep time without taking his or her eyes off the experiment itself. Once she or he has made the pendulum, the pupil must "calibrate" his device i.e., determine its period with the aid of a clock or watch. For example, if the pendulum oscillates 71 times per minute, then its period is

$$T = \frac{60}{71} = 0.86 \text{ SEC}$$

Experiment 1. Take a bottle filled with vegetable oil (better yet, pour some oil into a one-meter length of glass tubing, which will enable you or your family to use the oil for cooking after you have done the experiment). Close off the end of the tube with a rubber plug and position the tube vertically. Using an eye dropper, place a drop of water on the surface of the oil at the upper end and observe its motion.

How does the drop of water move? Is its motion rectilinear or curvilinear, uniform or non-uniform?

Make the necessary measurements and construct a graph of distance travelled as a function of time. What conclusions can you draw concerning the velocity of the drop of water? How is this expressed in terms of the graph you have constructed?

Mark the path travelled by the drop during a single period of the pendulum (you can do this with a paint brush dipped in a white substance of your own devising, such as toothpowder mixed with glue, oil or water).

Experiment 2. This experiment can be carried out on a smooth board or on a table. If the table is uneven, cover it with a sheet of thick paper. Tilt the table slightly, propping up its legs at one end. Next, take some round object (a ball, a checker, a hockey puck, a thread spool, etc) and have it roll down the inclined tabletop. Now make the required measurements and construct a graph of the path travelled by the rolling body as a function of time. The position of the body at a given instant can be marked by means of some small object such as a matchstick.

What conclusion or conclusions can you draw concerning the velocity of the rolling body?

Having caried out your experiments, analyze their results.

First of all we note that the motion of a drop of water through oil is rectilinear. The dependence of the distance travelled on time can be established by measuring the segments of path length corresponding to the duration of one, two, three, etc., oscillations of the pendulum. Suppose the following results were obtained as a result of your measurements:

t,sec	0.86	1.72	2.58	3.4
S,cm	3.4	6.9	10.4	14.0

It is easy to use these data to construct the graph of motion of the drop (Figure 2.14), which shows that the motion of the drop was indeed uniform. Its velocity was constant and given by the tangent of the slope angle of the curve with respect to the axis of abscissas. The velocity varies from drops of varying size.

Here is one possible result from measurements in the second experiment:

t,sec	0.86	1.72	2.58
S,cm	8.5	33	75

Having constructed the curve (Figure 2.15), we noted that the average velocity

$$V_{av} = \frac{S}{t}$$

is simply the tangent of the angle α_{av} while the velocity of any given point is the tangent of the angle formed by the tangent to the curve at that point (α^{i}, α^{ii}, α^{iii}). As is evident from the experiment, the velocity of a body rolling down a tilted surface increases continuously. In other words, what we are witnessing is accelerated motion.

EXPERIMENTS WITH A STROBOSCOPE

Having fitted a very simple stroboscope to a photogaphic camera, one can obtain interesting images of moving objects such as a ball, and then use these photographs to analyse various types of motion.

A stroboscope is essentially a disc made of heavy black paper with a whole through the camera lens "looks". The disc is mounted on a rubber plug fitted onto the axis of a small electric motor (Figure 2.16). During actual photographing the camera shutter stays open, but the position of the ball on the photographic film is recorded only at those instants when the camera lens is "looking" through the hole in the disc. The number of revolutions of the small electric motor is around 2400 rpm, so that a picture of the ball is taken at intervals of 1/40 sec (this interval can be halved by punching anther hole through the disc). The process is similar to motion picture photography. With stroboscopie photography, however; all of the images appear in a single frame, which is, of course, a more convenient way of representing the motion of a ball.

Experiment I. Free fall. Using the photographic image of a freely falling ball (Figure 2.17, left) we construct a table and plot the graph of path length as a function of time (Figure 2.18)

t,sec	0.06	0.12	0.18	0.24
S,m	0.017	0,068	0,15	0,27

Next we construct the table and graph of the velocity as a function of time (Figure 2.19). The velocity at a given instant is defined as the tangent of the angle , or, what is practically the same thing, as the ratio of the path increment ΔS to the corresponding time increment Δt.

t,sec	0.06	0.12	0.18	0.84
v,cm/sec	0.61	1.	1.8	2.4

We see from the graphs that the velocity of the ball gradually increases. The rate of increase of the velocity, i.e., the acceleration, is always the same (the graph of the velocity v as a function of t is a straight line). In other words, the free fall of a body is a type of motion with uniform acceleration.

It is likewise easy to calculate the free-fall acceleration g: the latter is equal to the tangent of the angle α, i.e., to the ratio $\frac{\Delta V}{\Delta t}$.

Let us calculate the value of this accelertion at the instant t = 0.24 sec.,

$$g = \frac{\Delta V}{\Delta t} = \frac{2.4\ m/sec}{0.24\ sec} = 10 m/sec^2$$

The value obtained by means of this very simple experiment is very close to the true value of g = 9.81 m/sec^2.

Experiment 2. Uniform motion along a circle. Such motion can be produced by "whipping in a circle" a ball made of cork or other lightweight material suspended on a thread (Figure 2.20). The distances between the images of the ball are equal, which means that its velocity is constant. However, the velocity vector continuously changes direction. Such motion is possible only if the acceleration vector is perpendicular to the velocity vector (centripetal acceleration $\vec{a}$).

The linear velocity of the ball can be determined by computing the circumferences $l = 2\pi R$ and the number of revolutions per second (or the time required for a single revolution $T = 1/n$). It is also easy to calculate the centripetal acceleration $a = V^2/R$. In the experiment to which the photograph refers, R = 0.25m, n = 40. Hence, $V = 2 m/sec$ and $a = 16 m/sec^2$.

The motion of a horizontally thrown ball. The velocity of the ball varies both in direction and in magnitude (Figure 2.17, right). It is easy to see that the horizontal component of the velocity remains constant. On the other hand, the vertical component varies according to a familiar law, i.e. as in the case of the free fall of a body.

An experiment involving a dynamometer

A device for measuring force, known as a dynamometer, can be made out of a spring and a straight-edge ruler, as shown in Figure 2.21. The spring is kept in place by means of a triangle-shaped piece of metal sheeting 2 already fitted with a hook-and-pointer 3. The wooden parts of the dynamometer (the ruler 5, the upper block 4 and the lower block 6) are held together with glue and small nails.

The free end of the spring is passed through a hole in upper block 4. The spring is screwed into the block, which makes it possible to vary its length in such a way as to achieve a specific rigidity value. For example, the rigidity of the spring can be such

that with a force of $0.01N \approx 1g$ might result in a stretching of the spring by 1mm. Once this is done, the lower end of the spring is snipped off, and the retainer screw holding the spring in a fixed position in the block is tightened. The dynamometer is now ready for use.

If a ready-made spring is not available, it can be readily fashioned out of a musical instrument string or piano wire. This can be done by means of a simple device such as that shown in Figure 2.22. A heavy-gauge wire (4-5 mm in diameter) is shaped into a handle 1. The lower end of the handle is slotted to receive the end of the piece of piano wire 3 to be used to fashion the spring. The handle is then clamped in a vise between two wooden blocks 2. If a vise is not available, a single clamp, such as that used to attach a meat grinder to a tabletop, can serve the same purpose.

A dynammeter can be used to perform a variety of experiments. Particularly worthwhile among these are those which enable the pupil to test out a theoretically justified assumption. Several examples of such experiments are set out below, followed by possible variations of solutions.

Problem 1: Suspend a weight on a thread (Figure 2.23). What will be the change in the tension of the thread if the weight is deflected in a horizontal direction?. At what angle of deflection will the tension change by a factor of two with respect to its initial value?

Problem 2: Stretch a thread over two blocks, e.g. over two thread spools (Figure 2.24). Suspend a weight from the lower end of the thread. Before doing the experiment, try to determine theoretically what the tension in the thread will be as the weight is lifted at a uniform velocity. Check out your results exprimentally.

Problem 3: Pass a thread through a length of glass tubing whose upper end has been made smooth by passing it through a burner flame. Suspend a weight such as a rubber plug from one end of the thread. Having shortened or lengthened the weighted segment of thread so that it measures 30-35cm, start twirling the weight around in a circle while keeping the free end of the thread in place with your finger. Try to have the weight describe a circle at a specified frequency, for example, one revolution per 0.5 sec. A second pendulum of length

$$l = \frac{T^2 g}{\pi^2} = \frac{1\,sec^2 \quad 9.8 m/sec^2}{9.8} = 1\,m$$

can be used as your device for measuring time.

A one-meter pendulum oscillates from one extreme position to the other in one second (its half-period).

Prior to doing the experiment, calculate the tension in the thread theoretically. Then verify your result experimentally, suspending an object of the necessary weight, such as a bag filled with copper coins, from the free end of the thread.

Problem 4: Place a box of matches on a horizontally positioned ruler (Figure 2.25). Calculate the maximum angle to which the ruler can be tilted without the box of matches sliding down its inclined surface. Check your result experimentally.

Possible solutions

1. As may be seen from Figure 2.26, the tension T in the string will increase as the weight is deflected (the force which counterbalances the tension in the thread is equal to the geometric sum of two forces, i.e. the gravitational force P and the force F acting on the weight in the horizontal direction). The tension in the thread doubles when $\angle = 60°$, i.e. when $\cos\angle = 0.5$. This can be readily verified by suspending the weighted thread from the dynamometer hook.

2. If you have been trying to determine the tension in the thread according to the parallelogram rule, you have been making a mistake. This rule does not apply in this case, since the thread slides over blocks and does not constitute an element of an arm. As can be readily shown by experiment, the tension in the thread is equal to the weight of the load (assuming that the friction is negligibly small).

Conclusion: fixed blocks do not afford any force advantage;

3. As may be seen from Figure 2.27, the force which imparts the centripetal acceleration required for circular motion to the body is the result of the geometric addition of the gravitational force acting on the weight of mass m_1 moving along a circular path and the weight of mass m_2.

The mass m_2 can be determined by applying Pythoras' theorem to the addition of forces:

$$m_2 = \frac{m_1 \sqrt{16\pi^4 R^2 \cdot 4 \cdot g^2}}{g}$$

If, for example $m_1 = 5g$, $n = 2\ \text{sec}^{-1}$, $R = 30\text{cm}$, then

$$m_2 = \frac{5\sqrt{16 \cdot 3.14^4 \cdot 30^2 \cdot 2^4 + 980^2}}{980} \simeq 24$$

Experimental results thus confirm the correctness of the calculation.

4. As can be seen from Figure 2.28, the tangent of the angle of inclination of a plane with respect to the horizon is given by the ratio of the components of the gravitational force acting on the load or weight, i.e.

$$\tan \alpha = \frac{F_1}{F_2}.$$

The magnitudes of these two factors are related by the expression

$F_1 = F_2 \mu - F_{fr}$, where F_{fr} is the friction force

Hence, the tangent of the limiting angle of the inclined surface at which the weight begins to slide down uniformly is equal to the coefficient of friction. Having determined the coefficient of friction of the matchbox using the dynamometer and having found the limiting slope angle with the aid of trigonometric tables, we see that the result obtained is verifiable experimentally. (Note, however, that the limiting angle as determined by experiment will be slightly larger due to the fact that friction at rest is somewhat larger than sliding friction).

Experiments with a loaded box may, for example, yield the following result: weight of the box and load F_2 - *120N*, the friction force acting as the box moves uniformly along the horizontal plane F_{fr} - *35N*. Hence,

$$\tan \alpha = \frac{F_1}{F_2} = \frac{32}{120} = 0.29, \quad \alpha = 16^\circ$$

The experimental result thus confirms the correctness of the calculations.

LAUNCHING OF A BODY AT A SPECIFIED VELOCITY

To launch a satellite in circular orbit around the earth, it is necessary to have the launcher rocket reach a velocity of about 8 km/sec. If the velocity is smaller, the rocket will fall back down to earth; if it is greater, it will take the satellite into outer space. How can the necessary velocity be achieved? In order to see this, let us try to solve several simpler but essentially very similar problems.

1. Why is it that a drop of water released onto a layer of vegetable oil drops through it at constant velocity? On what does the velocity of the drop depend?

2. Why is the motion of a flat object down an inclined surface uniformly accelerated? On what does the magnitude of its acceleration depend? If you have found the answer, they verify it experimentally, making a box, or some other object slide down an inclined plane with an acceleration of 0.5 m/sec^2.

3. If you have performed the previous experiment successfully, then try to make the same box (or an object such as wooden block) move horizontally with the same acceleration (Figure 2.29).

4. Once you have managed to solve this problem also, and once your reasoning and calculations have been proven correct by experiment, you can turn to the more complex problem stated in the outset, namely that of launching a body and having it achieve a specified velocity.

In order to perform this interesting experiment you need to construct a simple set-up (Figure 2.30). First of all, two nails need to be driven into a wall or wooden board a distance of 6-8 cm apart and at a height of 1.5 m from the floor. A white thread of length 1.5 m with looped ends is then cast over both nails. Two equal weights M_1 and M_2 of 80-100 g each are then attached to the ends of the thread. Make sure that these weights are of similar cylindrical shape.

A pendulum device with a paint brush at its lower end should be installed above the two nails (Figure 2.31). Having been dipped in ink or paint, the brush makes marks on the moving string as the pendulum oscillates.

The first thing to do is to see to it that one of the weights is able to move up and down at various constant velocities. Then a way has to be found to launch this weight in the downward direction with a specified constant velocity, e.g. 0.5 m/sec. It is very important that you find a way of doing these things yourself. Once you have coped successfully with this task, you can be confident that your knowledge of the basic laws of dynamics as provided for in the secondary school physics programme is entirely satisfactory.

Possible solutions to all of the above problems are set out in order to enable the pupil to check his own progress:

1. A drop of water dropped onto a layer of oil is acted on by two forces, namely the forces of gravity which acts downward, and a force directed upwards which acts to retard the motion of the drop. The latter is equal to the sum of the expelling force and the force of resistance exerted by the medium. At the start of motion, the sum of the expelling force and the resistance force is smaller than gravity, so that the motion of the drop is accelerated. However, the resistance force begins to be counterbalanced by the sum of the resistance and expelling forces. From then one, the motion of the drop proceeds by inertia and continues at the uniform velocity which the drop has had time to achieve (Figure 2.32). It is natural to suppose that the magnitude of this constant velocity for various spherically-shaped bodies will depend on their density and size. Indeed, experience shows that drops of water of larger diameter drop faster through a layer of oil. Similarly, if two balls of the same size but of differing densities (for example, a lead shot and a pea) are dropped onto the surface of an oil layer, the higher-density ball, i.e. the lead shot, will move through the oil layer faster.

2. A body will accelerate as it slides down an inclined plane when the geometric sum of the gravitational force P and the reaction R of the surface of the plane is greater than the force of friction F_{fr}. Knowing the coefficient of friction, we can calculate the angle of inclination of the plane required to achieve a specified value of the acceleration (Figure 2.33). Thus a body moves under the action of the difference between two forces

$$F_1 = F - F_{fr} = F - R\mu \qquad (\mu \text{ is the coefficient of friction})$$

Denoting the angle of inclination of the plane by we can simplify the resulting expression by reducing the number of unknowns which it contains, i.e.

$$F_1 = P\sin\alpha - P\cos\alpha \cdot \mu$$

But since $F_1 = ma$, while at the same time $P = mg$, what we have finally is the formula

$$\frac{a}{g} = \sin\alpha - \mu\cos\alpha$$

Since we have set for ourselves the task of launching a body with an acceleration of 0.5m/sec^2, the angle must be such as to satisfy the equation

$$\sin\alpha - \mu\cos\alpha = 0.05$$

Trigonometric function tables make it easy to choose the correct angle. For example, with a coefficient of friction of 0.45 the required angle of inclination is 24°30'.

To verify this conclusion experimentally, we can apply the formula giving the path length in the case of uniformly accelerated motion, i.e.

$$S = \frac{at^2}{2}$$

3. In order to launch a block or box along a horizontal table top with a specified value of the acceleration, we must first establish the mass of the dropping load. The appropriate calculation can be carried out on the basis of the second law of dynamics, i.e.

$$(m_1 + m_2)\,a = P - F_{fr} \qquad \text{or} \qquad m_1 a + m_2 a = m_2 g - F_{fr}$$

whence

$$m_2 = \frac{m_1 a + F_{fr}}{g - a}$$

Here is a possible result of the measurements

$m_1 = 0.12$ kg; $F_{fr} = 0.5N$ and therefore.

$$m_2 = \frac{0.12 \cdot 0.5 + 0.5}{9.8 - 0.5} \approx 0.060; \quad m_2 = 0.060 \text{ kg}$$

As in the previous case, experimental verification demonstrates the correctness of the theoretical solution.

4. As we saw in analyzing the first experiment (the fall of a drop of water through a layer of oil), a body acted upon by unbalanced forces will accelerate, whereas a body acted on by balanced forces will move uniformly at the velocity which it had managed to achieve by the instant when the forces became balanced. This experiment equips us with an idea helpful in solving the problem posed originally. The idea is this: a body must first experience accelerated motion, after which there will arrive an instant at which the forces acting on it become balanced.

First of all, a dynamometer should be used to measure the force of friction acting on the thread as it slides over the nails. This force must then be compensated by placing the required additional load on one of the equal weights. One must then see to it that the motion of the "augmented" load is uniform when that load is pushed downward. To achieve this, the brush-tipped pendulum, its brush having been tipped in ink, must be set in oscillatory motion. If the motion of the thread over the nails is uniform, the distances between the marks made by the brush will be equal.

If, moreover, a small additional load is placed atop the compensating "sinker" (for example, this can take the form of a large nail or a piece of heavy-gauge wire), then the gravitational force acting on this additional load will render the motion of the weight uniformly accelerated. Hence, all that remains to be done is to calculate the distance which the weights must travel in the uniformly accelerated mode in order to achieve the required velocity. At the instant when the required velocity is attained, the accelerating sinker (nail or wire) must be removed, whereupon the weights begin to move by inertia (inasmuch as all of the forces are in equilibrium, i.e., the algebraic sum of all of the forces acting on the given body is equal to *0*).

For example, let $M_1 = M_2 = 0.12$ kg, the friction force $F_{fr} = 0.87$ N the mass of the compensating load $m_1 = 0.087$ g, and the mass of accelerating load (nail or wire) $m_2 = 0.020$ g. The overall system of weights then moves with an acceleration which can be determined by the equation

$$m_2 g = a(2M + m_1 + m_2).$$

From this we obtain

$$\frac{m_2 g}{2M + m_1 + m_2} = \frac{0.020}{2.0.12+0.087+0.020} \approx 0.56;\ a \approx 0.56 \text{m/sec}$$

It is now easy to establish the distance which the weights must travel in order for the required velocity, for example 0.50 m/sec to be attained.

$$S = \frac{v^2}{2a} = \frac{0.50^2}{2.0.56} \approx 0.23;\quad S \approx 0.23m$$

The two nails driven into the wall at the required distance apart (23cm) compensate the additional load.

ELASTIC COLLISION OF BALLS

The elastic collision of balls is remarkable not only because of the fact that the velocities of the colliding bodies change instantaneously, but also by virtue of the fact that their total kinetic energy and momentum remains constant. Knowing this, one can perform several interesting experiments helpful in gaining an understanding of what is basic in such collisions.

To carry out the appropriate experiments one needs three steel balls (of which two are of the same size), some lengths of thread, some strong cement for attaching the threads to the steel balls (if appropriate holes are not provided in the latter), a ruler and a dynamometer or scale. A stroboscopic photography setup is also very helpful in carrying out such experimentts.

Experiment 1. Take two steel balls of equal size and suspend them on long threads from a place such as a window sill so that they touch each other as they hang. Draw one of the balls some distance away to one side from its equilibrium position and then release it so that the moving ball hits the other one "head on" (Figure 2.34).

What happens when the balls collide? What is the maximum deflection of the other ball after it has been struck and how does it depend on the maximum deflection of the first ball prior to the collision?

What is the relationship between the quantities if the masses of the balls are unequal?

Experiment 2. Try to produce an off-centre collision of balls of equal mass. Observe what happens over several different tries (it is at this stage that stroboscopic photography comes in handy). Try to explain what happens without outside help, using simple mathematical transformations of formulae which you already know. After checking your results independently, read over the possible alternative versions of solutions of the stated problem.

1. When a moving ball collides with another ball of the same mass which is at rest, and when both balls are elastic, the balls exchange momentum and energy. Inasmuch as the collision is elastic, it is not only momentum, but also mechanical energy which is conserved. For this reason, regardless of the distance to which the first ball is deflected, the target ball will be deflected by (almost!) the same distance, while the striking ball will come to rest. This effect is then repeated in the reverse direction, etc.

If the masses of the balls are unequal, then, even though their collision involves conservation of both momentum and energy, the picture is not quite so simple. In order to calculate the velocities of each ball after collision; it is necessary to solve a system of two equations, namely

$$\frac{m_1 v_1^2}{2} + \frac{m_2 v_2^2}{2} = \frac{m_1 u_1^2}{2} + \frac{m_2 u_2^2}{2}$$

and

$$m_1 v_1 + m_2 v_2 = m_1 u_1 + m_2 u_2$$

where m_1 and m_2 are the masses of the first and second balls, v_1 and v_2 are their velocities prior to collision, and u_1 and u_2 are their velocities after the collision.

If the second ball is at rest, i.e. if $v_2 = 0$, then the solution of the equations yields the following results:

$$U_1 = \frac{(m_1 - m_2)}{m_1 + m_2} \quad ; \quad U_2 = \frac{2 m_1 v_1}{m_1 + m_2}$$

where $v^2 = 2gh$ i.e. v^2 is proportional to h. With small angles of deviation of the thread from the vertical, it can be assumed with a high degree of precision that

$$h = \frac{l^2}{2R}$$

A perpendicular dropped from any point along the circle onto a diameter, is the mean proportion between its segments, i.e. h is proportional to l^2 which means that v is proportional to l.

But since $u_1 = v_1 = l_1 = l_1$ and $u_2 = v_1 = l_2 = l_1$ it follows that:

$$l_1 = l_1 \frac{m_1 - m_2}{m_1 + m_2} \qquad l_2 \frac{2 m_1 l_1}{m_1 + m_2}$$

This means that, knowing the masses of the balls and the initial deflection l, from the position of equilibrium of the first ball, we can predict the maximum deviations of the balls following their elastic collision. For example let m_1 = 0.090 kg, m_2 = 0.035 kg and l_1 = 0.20 m. In this case, it is easy to obtain the result that l_1 = 0.088 and $l_2 \approx 0.29$ m

The experiment once again confirms the correctness of the calculations.

2. Now let us consider the case of an off-centre elastic collision. Regardless of how many trials you perform, all of them lead to one and the same result, namely that balls of equal mass will move off at a right angle to each other. The rule of vector addition suggests that the phenomenon occurs in such a way that the following equation is always valid:

$$v_1^2 = u_1^2 + u_2^2$$

It is easy to see that this is the consequence of the conservation of kinetic energy in an elastic collision,

$$\frac{mv^2}{2} = \frac{mu_1^2}{2} + \frac{mu_2^2}{2}$$

Figure 2.35 shows a photograph which enables you to convince yourself of the validity of this hypothesis. Measuring the distance between the images of the balls before and after collision, we find that

$$l_1^2 = (l_1^1)^2 + (l_2^1)^2$$

which confirms the validity of the formula.

The angle at which the balls fly off away from one another makes it possible to judge the mass not only of balls, but of elementary particles as well. The photograph of Figure 2.36 obtained with the aid of a Wilson cloud chamber, shows the collision of two α-particles. As you can see, the tracks left by the particles after they have collided likewise form a right angle.

FIRING A PROJECTILE WITH A SPRING-LOADED CANNON SO THAT IT WILL TRAVEL A GIVEN DISTANCE

A toy spring-loaded cannon or pistol, a piece of plasticene, some thread, a ruler and a few other easy-to-find materials will allow you to perform several interesting experiments in mechanics. Here is an example. It is difficult to hit a target from a spring-loaded cannon at first try. On the other hand, it is possible to calculate the velocity of the projectile, to verify the calculation experimentally, and then to direct the projectile to its target.

If you have some steel wire of diameter 0.3 - 0.5 mm, some paper and glue, then you can readily construct the kind of cannon you need for your experiment. The wire should be wound around a core clamped between two pieces of wood held in a vise (Figure 2.22). Your spring is now ready. The barrel of the cannon is fashioned out of several layers of thick paper rolled into a tube around the spring and cannonball. The gun-carriage can be any massive base such as a household iron (Figure 2.37).

Now, when everything is ready, let us solve several problems and check of the correctness of the results experimentally.

Problem 1. Having loaded the cannon with the ball and applied a specific compressive force to the spring, determine the initial velocity of the projectile (cannonball).

Remark. In order to determine the mass of the projectile, as well as the compressive force applied to the spring or its elastic coefficient, you can either use your homemade spring dynamometer or suspended weights.

Problem 2. Make a ballistic pendulum, i.e. a hollow ball in the form of a piece of plasticine suspended by two long threads (Figure 2.37). Having fired the ball from the cannon into the hollow of the pendulum weight, determine the velocity of the missile on the basis of the deflection experienced by the pendulum.

Problem 3. Having positioned the cannon vertically, calculate the maximum height to which the projectile can rise.

Problem 4. Position the cannon horizontally over the table top. Determine the range of the cannonball on the basis of its calculated velocity.

Problem 5. By calculation only, try to hit a target located some specific distance away from the muzzle of your cannon.

If the measurements are carried out with sufficient care, the coincidence between the calculated and experimental results is quite amazing. Here is how the problem set above can be solved:

1. The initial velocity of a projectile fired from the spring-loaded cannot can be calculated on the basis of the fact that the potential energy of the compressed spring is almost entirely converted into the kinetic energy of the projectile upon firing.

$$\frac{kx^2}{2} = \frac{mv_0^2}{2}; \quad \text{hence } v_0 = \sqrt{\frac{kx^2}{m}} \qquad (1)$$

where v_0 is the initial velocity of the projectile, k is the coefficient of elasticity of the spring, x is the spring compression and m is the mass of the projectile.

The coefficient of rigidity of the spring can be determined from the ration of the deforming force applied to the amount of deformation. For example, if the application of a deforming force of $F = 1$ N the compression turns out to be $x = 22$ mm, then $F:x = 45$ N/m (Figure 2.38).

Knowing the coefficient of rigidity of the spring, one can readily determine the magnitude of the deforming force from the formula $F = kx$.

For example, let the compression of the spring be equal to 2 cm, in which case $F = 45$ N/m x 0.02 m = 0.9 N. For this value of spring compression, the velocity of a projectile (small ball) of mass 8.5 g will be equal to 1.7 m/sec.

2. A ballistic pendulum can be used to determine the velocity of a projectile by applying the law of conservation of momentum. (The law of conservation of mechanical energy cannot be used here, since part of the mechanical energy in an inelastic collision is converted into heat). The momentum of the projectile prior to the impact will be equal to the momentum of the system consisting of the ballistic pendulum together with the projectile lodged in it

$$mv_0 = (m + M)v \text{ hence}$$

$$v_0 = v\,\frac{m + m}{m} \qquad (2)$$

Where M is the mass of the pendulum and v is its initial velocity.

The mass of the ballistic pendulum is determined by weighing it, while its initial velocity can be determined from the maximum deflection from the equilibrium position, when the kinetic energy acquired by the pendulum is fully converted into potential energy. Here $v^2 = 2gh$ where h is the height to which the pendulum rises at maximum deflection. For small angles of deflection it can be assumed with considerable accuracy that

$$h = \frac{l^2}{2R}$$

where l is the maximum deflection of the pendulum from the equilibrium position and R is the length of the pendulum suspension. It can therefore, be assumed that

$$V = \sqrt{\frac{2gl^2}{2R}} = l\sqrt{\frac{g}{R}} \qquad (3)$$

Hence in order to determine the initial velocity of the ballistic pendulum it is sufficient to measure the length of the pendulum suspension and its maximum deflection from the equilibrium position after the projectile has struck it.

We are now ready to write out the final expression for the velocity of the projectile.

$$v_0 = l\sqrt{\frac{g}{R}} \cdot \frac{m+m}{m}$$

and can go on to perform the experiment, make the required measurements, and solve the second problem. Here is the possible result which might be arrived at in the case of the second problel: $m = 0.0085$kg, $M = 0.060$kg. $R = 1.41$ m, $l = 0.085$ m, $v_0 = 1.70$ m/sec.

3. The maximum height to which the projectile will rise can be calculated by applying the formula $H \approx 0.15m$

Remark. In the case of shots directed either vertically upward or at angles to the horizon, the magnitude of the spring compression x used to obtain the previously calculated initial velocity of the projectile must be measured from the point to which the front end of the spring has been lowered by the weight of the projectile.

4. The possible range of the projectile with the cannon positioned horizontally can be calculated on the basis of the following considerations. The curve traced by the projectile is a parabola. In other words, the projectile moves by inertia with a constant horizontal velocity v_0 and at the same time drops with the constant acceleration g. Knowing the height at which the canon is positioned, we can determine the time of flight of the projectile

$$h = \frac{gt^2}{2} \quad \text{whence} \quad t = \sqrt{\frac{2h}{g}} \qquad (4)$$

Knowing the initial velocity v_0 of the projectile and the time it is in flight, we can also determine its range.

If, for example, $h = 13$ cm, then $S = 28$cm.

In order to ensure that the projectile hits a given target (such as a box or a tin

can) one can proceed in either of two ways, namely by adjusting the deformation of the spring or by appropriately setting the angle of the cannon with respect to the horizon (Figure 2.39). Let us begin by considering the first method of targeted fire.

From formula (4) it follows that $v = S\sqrt{\frac{g}{2h}}$

Comparing this formula with formula (1), we obtain

$$x = \sqrt{\frac{m}{k}} \cdot S\sqrt{\frac{g}{2h}} = S\sqrt{\frac{mg}{2hk}} \qquad (5)$$

Complementing the numerical example cited previously with the additional information that the distance to the target is $S = 40$ cm, we can readily find the spring compression necessary to hit the target, namely $x = 3.2$ cm.

Now let us suppose that the spring compression is a specified constant, while the range of the projectile has to be regulated by adjusting the angle of fire.

The vector of the initial velocity can be decomposed along two directions, namely along the verticle $v_v = v_0 \sin\alpha$ and along the horizontal $v_h = v_0 \cos\alpha$. The distance travelled by the projectile is now given by the formula

$$S = v_h t = v_0 \cos\alpha \cdot t = v_0 \cos\alpha \cdot \frac{v_0 \sin\alpha}{g} = \frac{v_0^2 \sin 2\alpha}{g}$$

whence

$$\sin 2\alpha = \frac{Sg}{v_0^2} \qquad (6)$$

We can now find the angle (for example, by using trigonometric tables). Let us suppose that the spring compression is the same as in the previous example, and that the distance to the target is 30cm. In this case $\sin 2\alpha = 0.98$; $2\alpha = 80$; $\alpha = 40°$. With the cannon tilted to this angle, the projectile is certain to hit the target.

SOME ENGINEERING DESIGN ASSIGNMENT FOR ENGINEERING PHYSICS CIRCLES

We shall confine ourselves to mentioning just a few of the possible pupil assignments involving the construction of models. Things which pupils and groups of pupils like to build including automobiles, scales and balances, motor boats, propeller-driven sledges and automatic regulators. The design calculations involved are relatively simple, so that if the project is completed with sufficient care, surprisingly good agreement of the expected and experimental results can be achieved. Let us illustrate this by an example.

Pupils are asked to "invent" a model automobile which will move with a specified acceleration and will achieve a specified velocity.

Those who have completed the creative laboratory exercises in dynamics as set out above are fully prepared to tackle this kind of creative assignment.

POSSIBLE SOLUTION

A schematic drawing of the model automobile is shown in Figure 2.40. The automobile is driven by the weight of a falling object whose mass can be found from the following equations

$$m_2 g - F_{fr} = (m_2 + m_t) a$$

$$m_2 = \frac{m_t^2 a + F_{fr}}{g - a}$$

where m_t is the mass of the trolley, m_2 is the mass of the load, F_{fr} is the force of friction, g is the free-fall acceleration, and a is the specified acceleration.

In order to have this automobile move with a specified velocity it is necessary to calculate the distance it must travel in order to achieve that velocity, i.e.

$$S = \frac{v2}{2a}$$

Clearly, if this distance is equal to the height from which the load descends, the automobile will reach the specified velocity precisely over that distance.

The correctness of the above calculation can be verified by means of one of the kinematics devices already constructed by the pupil (marker, stroboscope or automatic recorder).

The following asssignment is a useful adjunct to the study of statistics.

Pupils are asked to design a postal scale to weigh letters of up to 200 g, without using either a spring or a set of weights.

POSSIBLE SOLUTION

A diagram of the scale appears as Figure 2.41. Such a scale can be graduated in advance by applying the formula

$$m_2 g l_2 = m_1 g l_1; \qquad m_2 = \frac{m_1 l_1}{l_2}$$

where m_1 is the mass of the weight attached to the disc and m_2 is the mass of the item to be weighed.

In covering the unit entitled "Work and energy", pupils may be asked to carry out a number of assignments involving the design of various kinds of generators and motors. Let us consider just one example of such an assignment.

The task is to construct a propeller-driven sledge whose miniature motor runs on a simple flashlight cell.

POSSIBLE DESIGN

A diagram of the model is shown as Figure 2.42. A piece of sheet metal is cut and bent to make a platform for the battery together with the skis and ski supports. This structure together with the electric motor is attached to the cell with rubber bands.

The problem now comes down to determining correctly the angles of incidence (rigging angles) of the propeller (Figure 2.43).

The velocity of the oncoming airstream is composed geometrically of the velocity of the sledge and the velocity of the air in the plane of the propeller (equal in magnitude to the linear velocity of an element of a rotating propeller blade). We can see from the figure that the angle of incidence is given by

$$\phi = 90 - (\alpha_1 + \alpha)$$

The angle α_1 can be determined from the equation

$$\tan\alpha_1 = \frac{v_2}{v_1} - \frac{\omega r}{v_1}$$

where r is the distance between the given cross-section and the axis of rotation.

Before the pupils are asked to do the appropriate calculation, they must be able to understand that the "angle of attack" is , and which angle of attack is most advantageous in designing the propeller (screw) profile.

The velocity of the propeller-driven sledge can be determined from the equation

$$v = \frac{N\eta}{F_{fr}}$$

where N is the power of the miniature motor and F_{fr} is the force resisting the motion of the sledge (see the sledge design diagrams in Figure 2.44).

Another assignment involves designing an angular velocity regulator for a wind motor.

Youngsters living in rural areas are often fascinated by the design of wind motors which can be used for various purposes, such as sources of power for electricity generators or water pumps. But wind motors have the disadvantage of operating non-uniformly, their speed depending on wind velocity. This drawback can be eliminated by constructing an automatic rpm regulator.

POSSIBLE SOLUTION

A schematic diagram of the "invention" is shown in Figure 2.45. At normal rpm values, the trimmer at the end of the blade "cuts across" the oncoming air stream. When the angular velocity exceeds a certain value, the moment of force of the cylindrical spring which holds back the blade becomes insufficient. The blade then switches from the "across" to the "along" position and puts a brake on the rotation of the wind wheel.

Thus, proper choice of assignments involving the design of models is a means of meaningfully organizing the creative activity of pupils in various specific fields of physics. Any supplementary knowledge required for successfully coping with such assignments is either supplied by the supervising teacher or sought out in reference books by the pupils themselves.

Such an approach is suitable for organizing the work of a circle on "Engineering physics modeling". This is the type of circle which appeals particularly to youngsters with an aptitude for creative engineering. It serves to cultivate a deeper interest in physics, giving the leaner a more profound grasp of the subject and promoting the development of creative abilities through the construction of physics devices and the performance of experiments using such devices.

Creativity in such a group is based on the principles of "subjective novelty". In other words, the teacher sets design tasks for which he already has one or several possible solutions. This, of course, does not preclude the pupils arriving at new and different solutions of their own.

The starting point for such creative and inventive work on the part of pupils is the statement of the problem. This statement must flow naturally from the requirements of experiments set in connection with a particular subject area within the physics course. Incentives for posing a particular problem include formal classroom lectures, informal talks with the teacher, science films and field trips to various laboratories and industrial enterprises. Each pupil is asked to solve a problem put before him independently by presenting his proposal in the form of a project. This includes a general drawing, a kinematic or electrical diagram, drawings of the more essential details of the time to be constructed, mathematical computations, and a brief description of the proposed design. The more interesting and successful versions of the solution are discussed in class. After such a discussion, pupils get together to construct one or several of the selected designs with due allowance for the available facilities, resources and time. Once constructed, the devices are often exhibited in the school, after which they become part of the physics workshop equipment.

Sessions are conducted in the form of introductory lectures or talks which provides an opportunity for stating the problem and for communicating the required information. Such work should be so organized that the pupils work independently at developing projects, solving creative assignments, and actually building their own devices.

Out-of-class work by teachers with circles of pupils particularly interested in creative engineering physics offers broad opportunities not only for developing the creative ability of the youngsters, but for enhancing the learning performance of the class as a whole. Moreover, this form of work enables the teacher to achieve results which cannot be attained within the usual classroom context. The following considerations are particularly relevant in this connection

- initiatives in choosing subject areas to be worked on and the form(s) in which the work is to be executed must come entirely from the pupils themselves;

- the time devoted for carrying out assignments must not be limited to set classroom or laboratory hours;

- a group of genuinely enthusiastic youngsters can readily cope with fairly difficult problems, such as acquiring the necessary equipment, materials and instruments;

- work in a special-interest group is inevitably characterized by a spirit of friendly and creative cooperation - something which in and of itself encourages creative ctivities and learning.

All that the teacher need to concern himself with is the channeling of boundless youthful imagination and enthusiasm towards activities which are genuinely feasible. This is necessary to maintain and strenthen the young person's faith in his or her own creative powers, providing a happy impetus for persevering in work and study.

2.5. ANNEX II

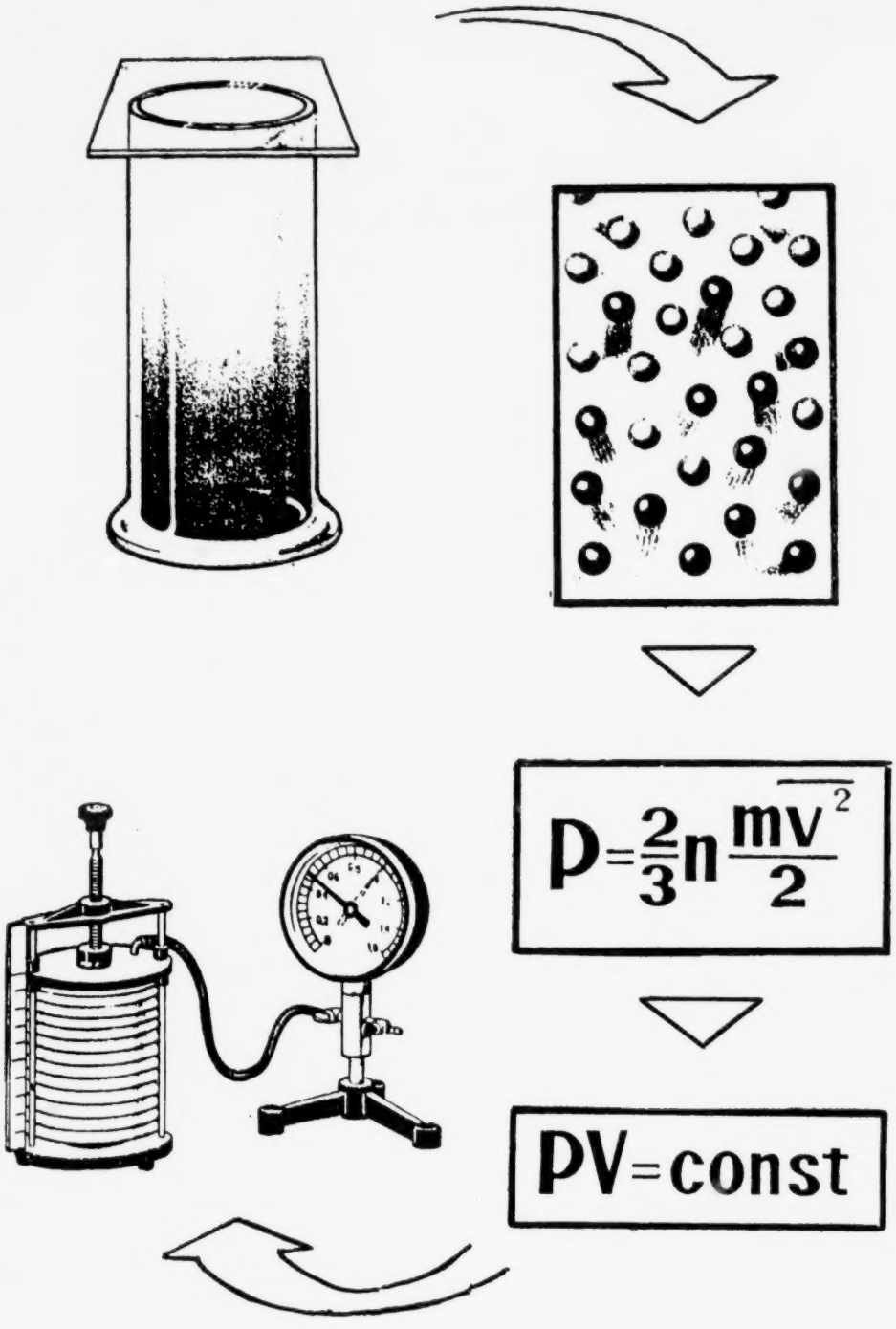


Figure 2.1

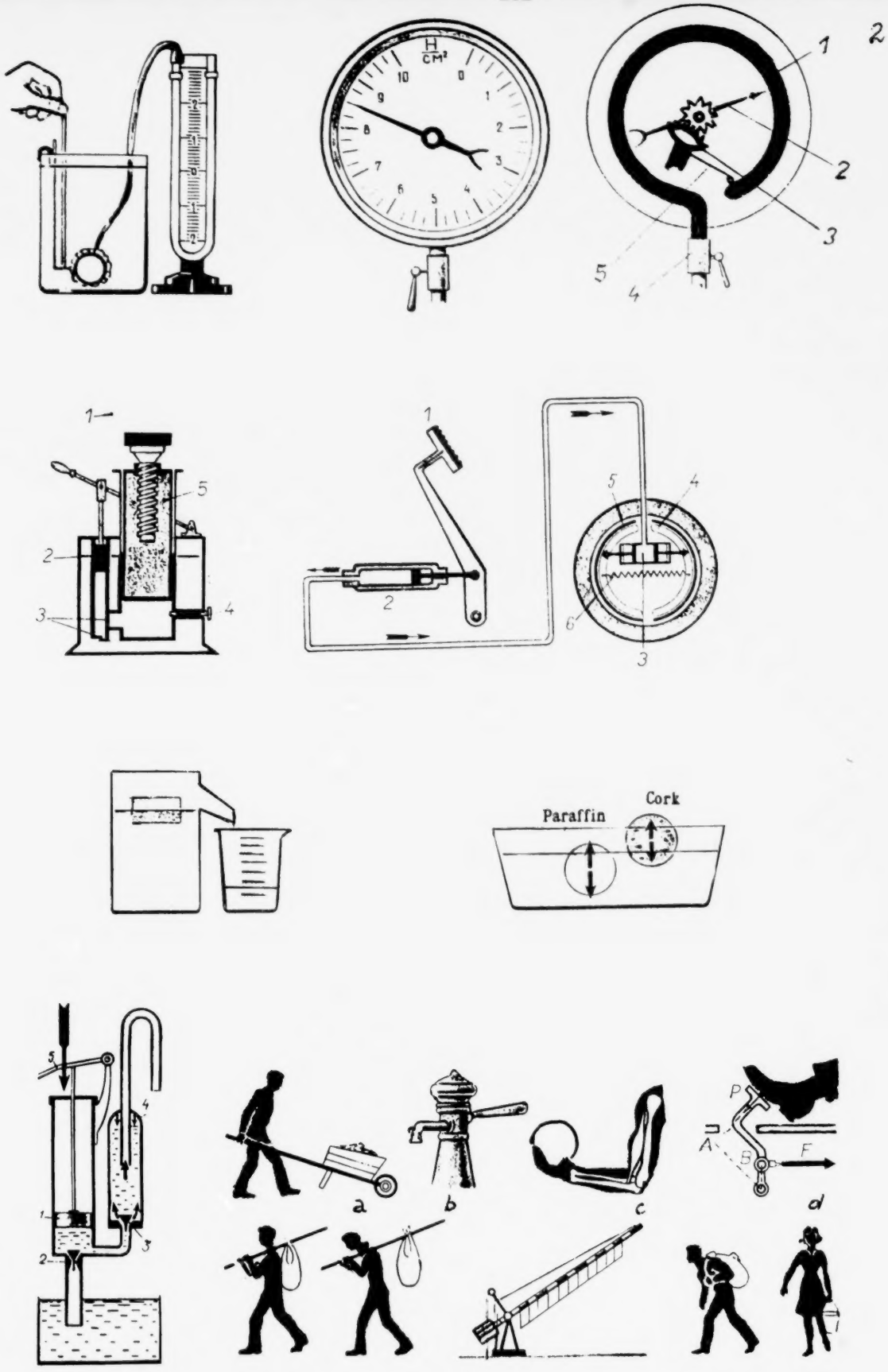


Figure 2.2

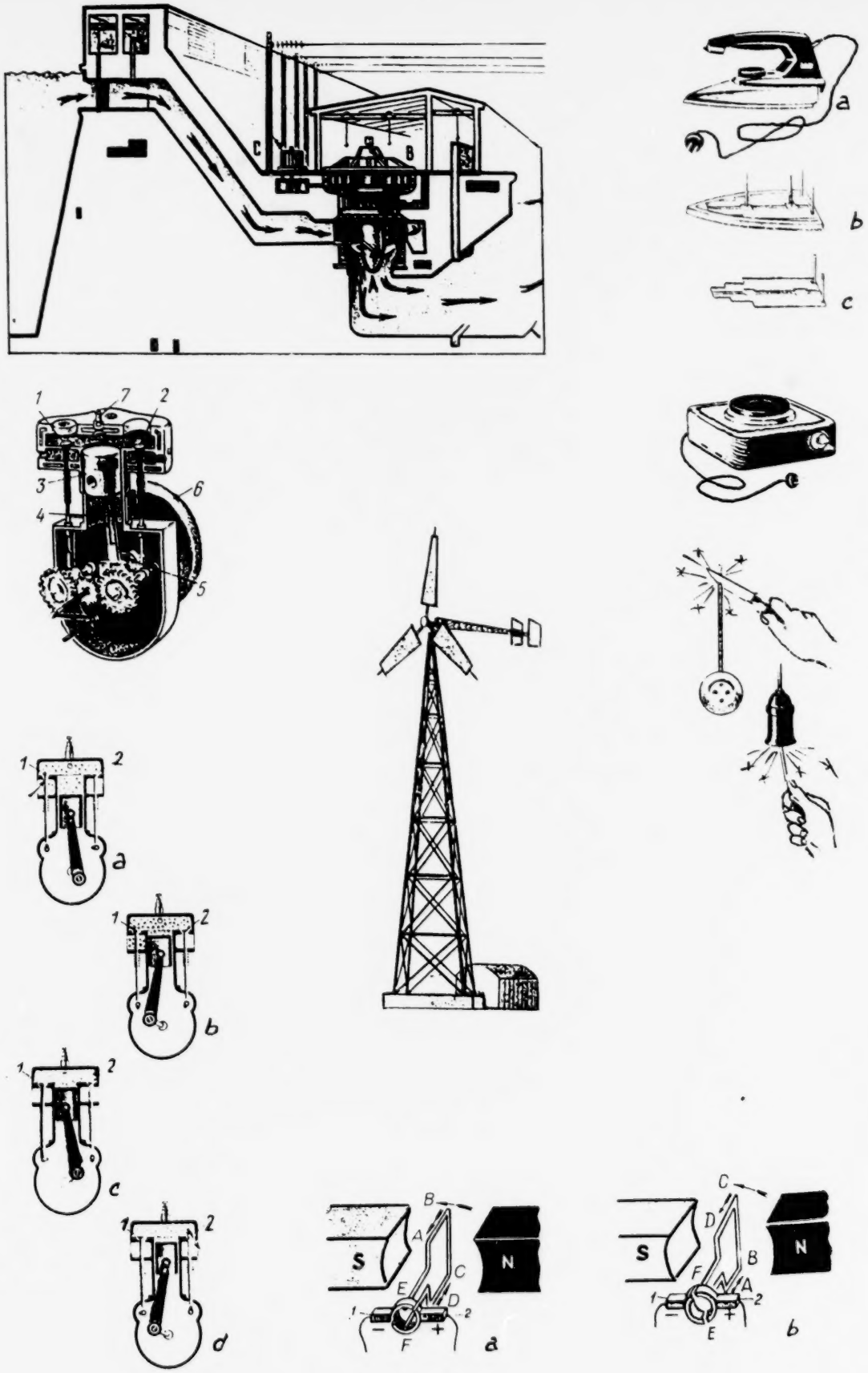
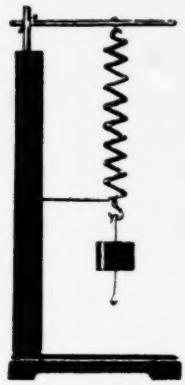
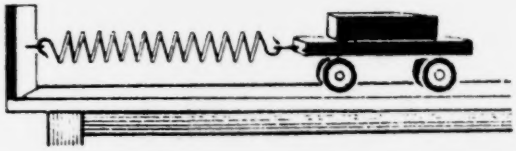
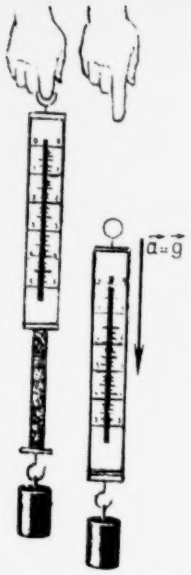


Figure 2.3

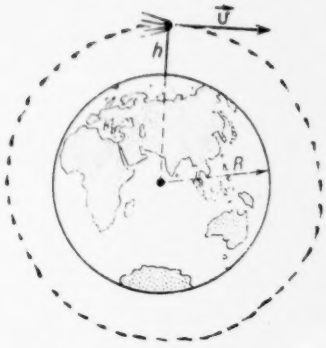


$F_{ee} = -kx$





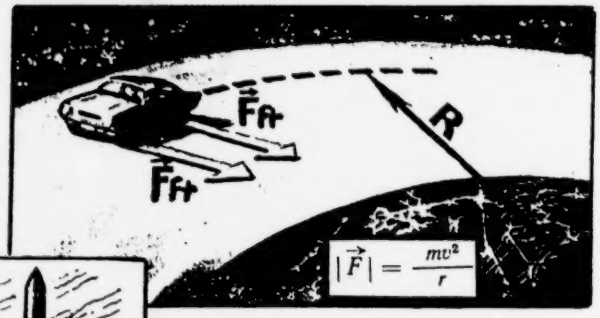
$P = m(g - g) = 0.$

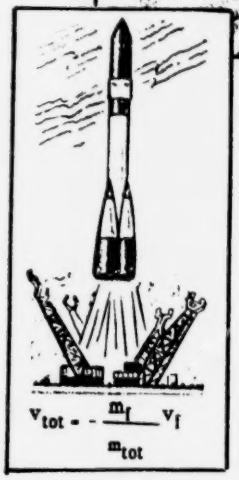


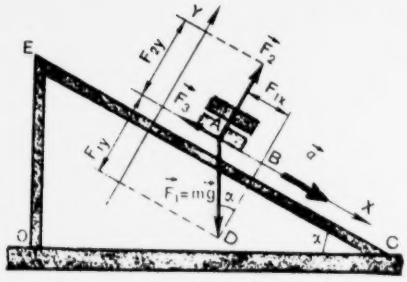
$$|\vec{a}| = \frac{\vec{F}}{m} = G\frac{M}{(R+h)^2}.$$

$$\frac{v^2}{R+h} = G\frac{M}{(R+h)^2},$$

$$v = \sqrt{G\frac{M}{R+h}}.$$

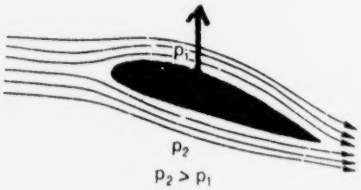


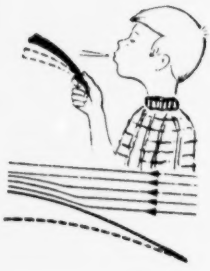


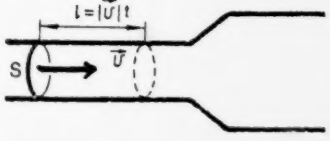


$$m\vec{a} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3.$$

Рис. 190

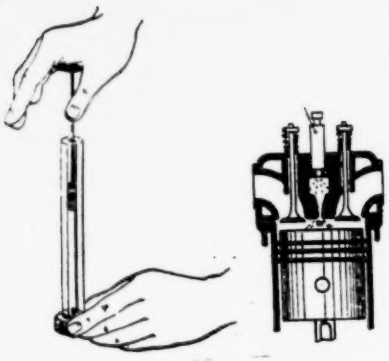






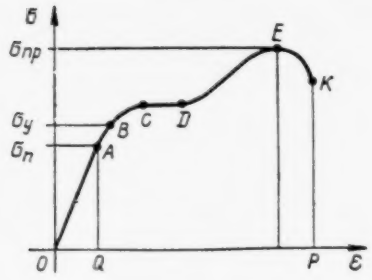
$$S_1|\vec{v}_1| = S_2|\vec{v}_2| = S_3|\vec{v}_3| = S_4|\vec{v}_4|.$$

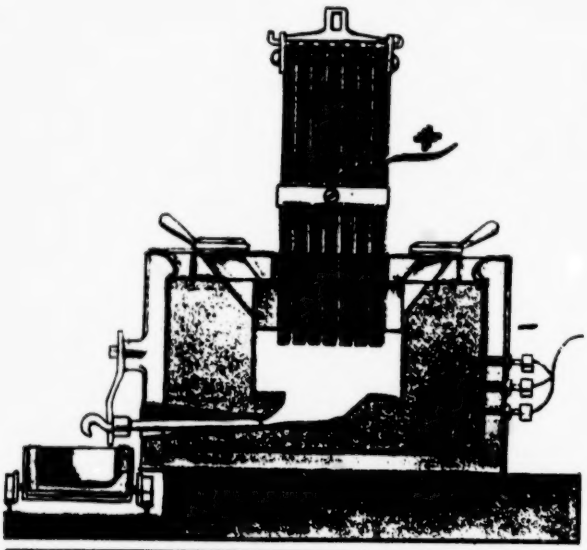
Figure 2.4

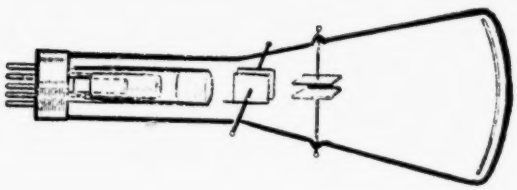


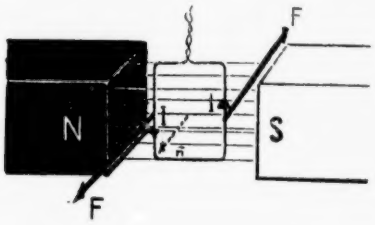
$$\eta = \frac{A'}{Q_1} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1}.$$

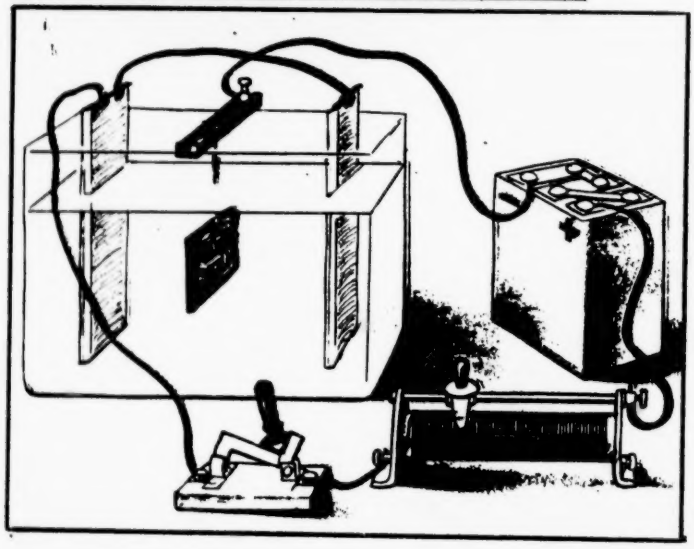
$$\eta_{max} = \frac{T_1 - T_2}{T_1} \cdot 100\%$$

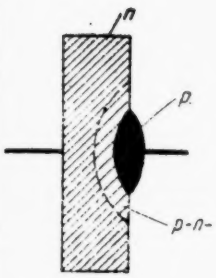












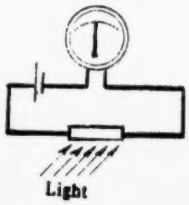


Figure 2.5

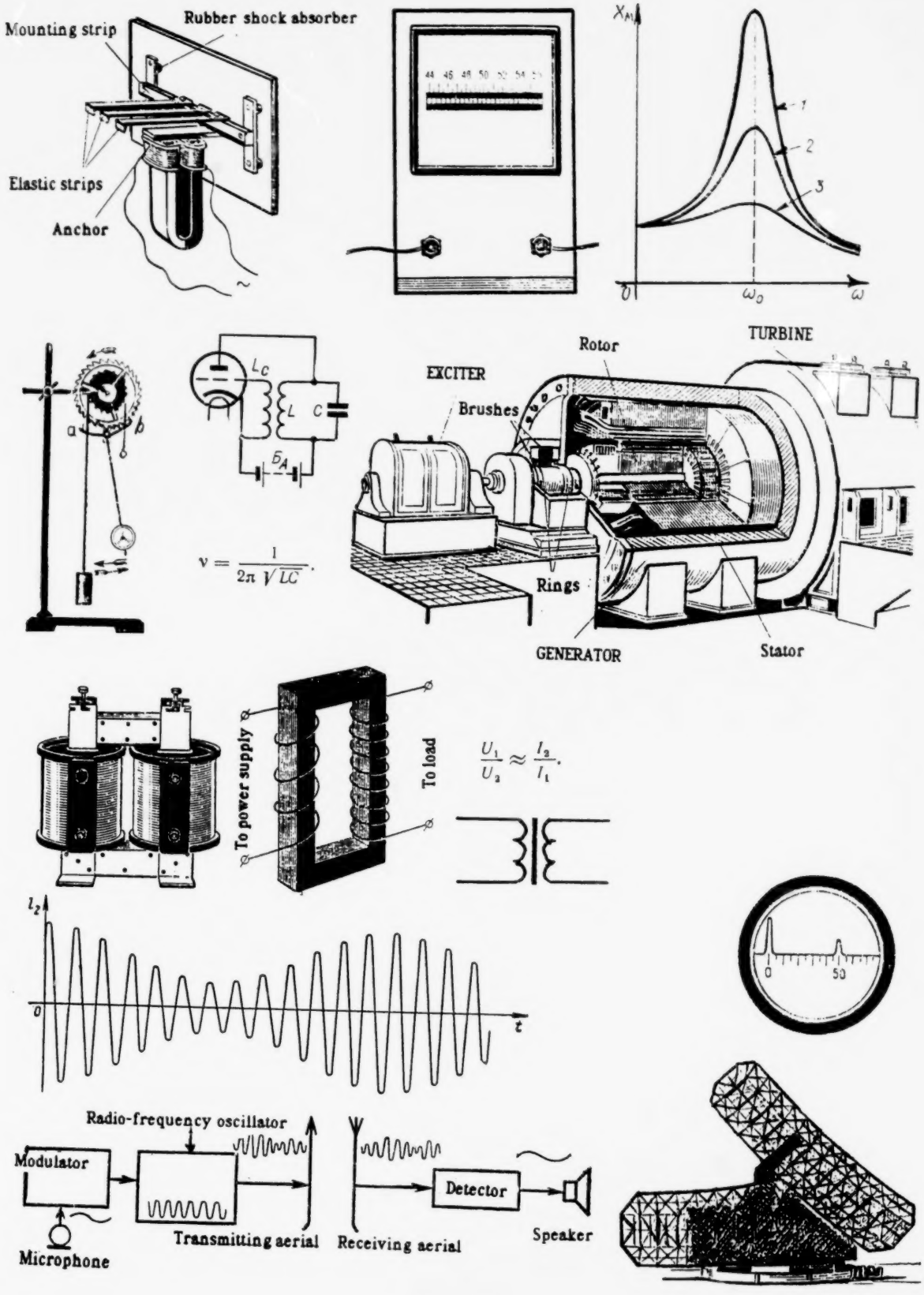
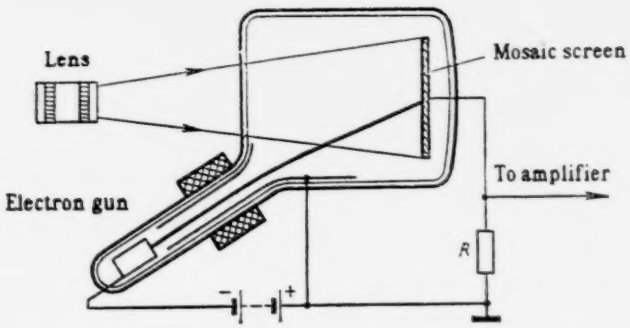
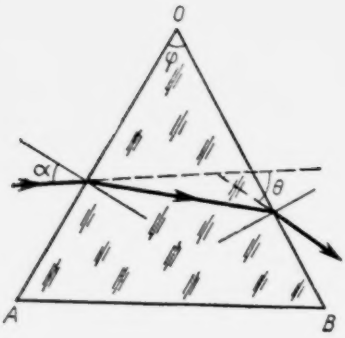
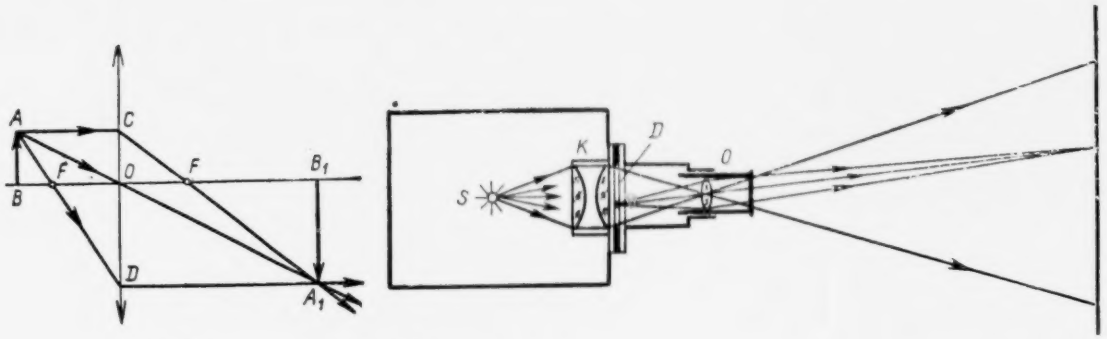
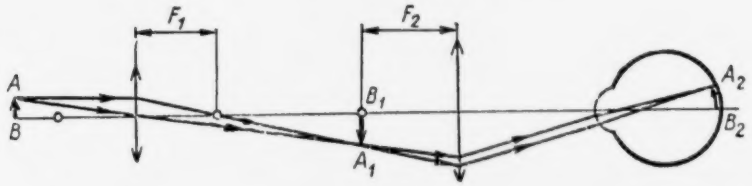

Mounting strip
Rubber shock absorber
Elastic strips
Anchor
X_m
1
2
3
0
ω_0
ω
a
b
L
C
$\mathcal{E}_A$
$\nu = \frac{1}{2\pi\sqrt{LC}}$.
TURBINE
Rotor
EXCITER
Brushes
Rings
GENERATOR
Stator
To power supply
To load
$\frac{U_1}{U_2} \approx \frac{I_2}{I_1}$.
I_2
0
t
0
50
Radio-frequency oscillator
Modulator
Microphone
Transmitting aerial
Receiving aerial
Detector
Speaker

Figure 2.6









$$\frac{1}{d}+\frac{1}{f}=\frac{1}{F},$$

$$\frac{1}{d}+\frac{1}{l}=D.$$

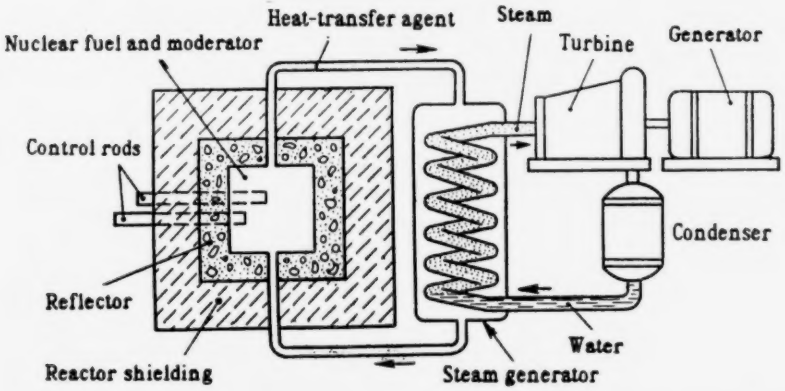


Figure 2.7

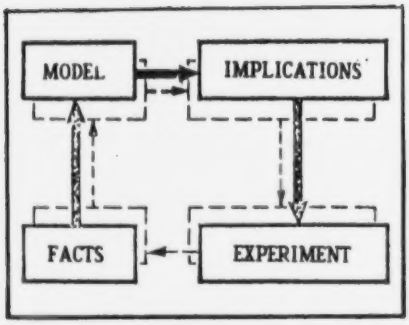


Figure 2.8. Diagram showing the inter- relationship of initial facts (findings), an abstract model (hypothesis), theoretical implications and experiment in creative thinking in the natural sciences.

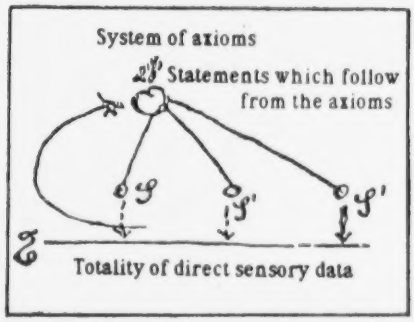


Figure 2.9. Einstein's diagram of creative thinking in science

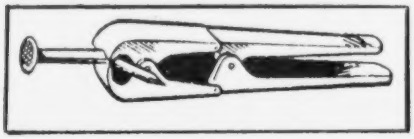


Figure 2.11. Illustration accompanying Problem 2.

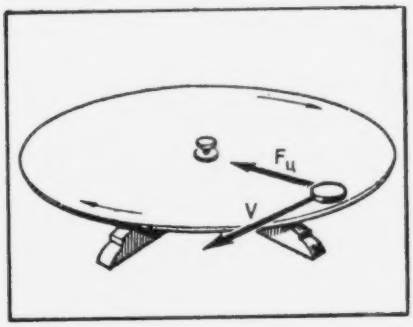


Figure 2.10.Schematic drawing of a device for determining the coefficient of friction

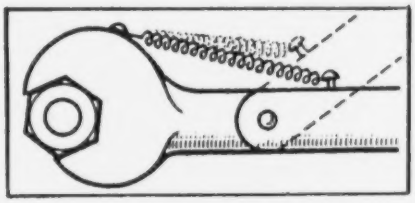


Figure 2.12 Illustration accompanying Problem 3.

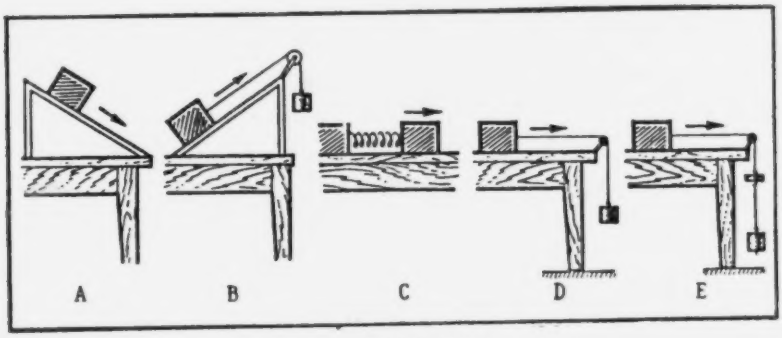


Figure 2.13

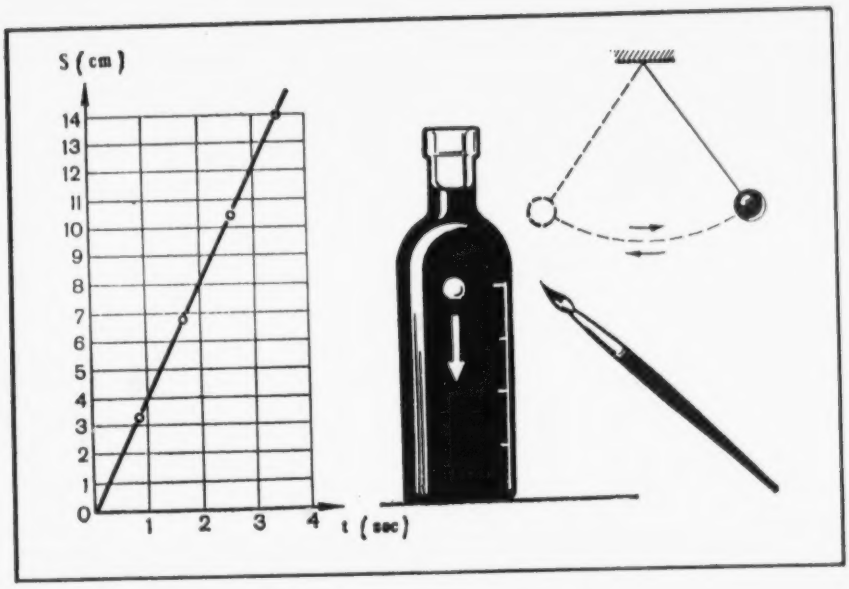


Figure 2.14. Motion of a drop through a lighter liquid.

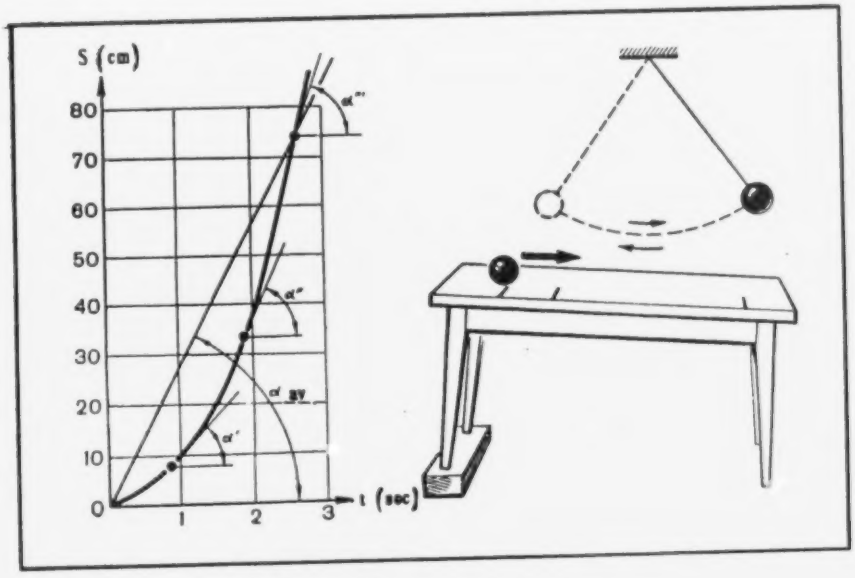


Figure 2.15. Motion of a ball rolling down an inclined plane.

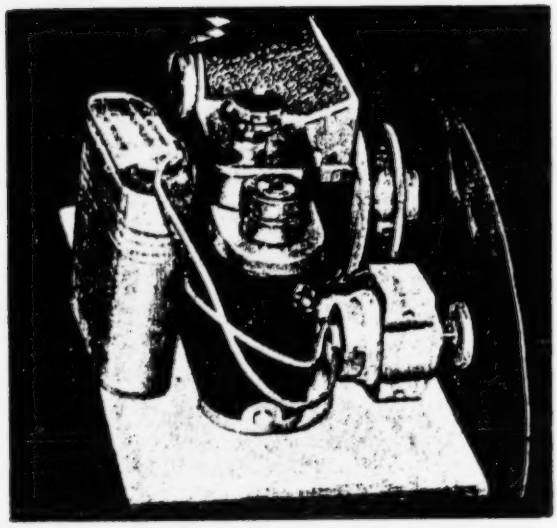


Figure 2.16. Home-made stroboscope powered by a miniture electric motor which can be used to photograph various kinds of motion.

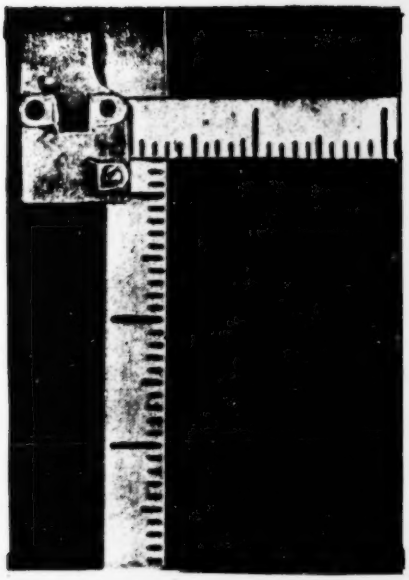


Figure 2.17. Stroboscopic photograph of a freely falling ball

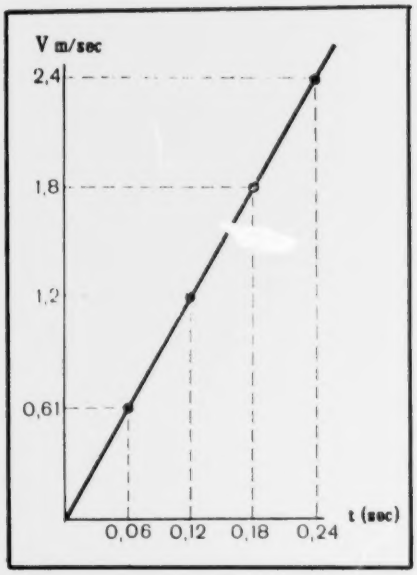


Figure 2.19. Graph of velocity as a function of time in free fall

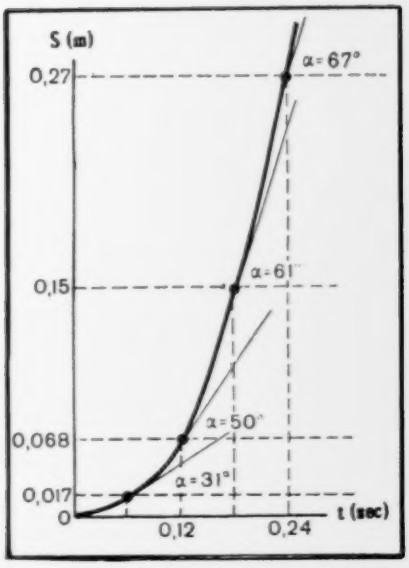


Figure 2.18. Graph of path length as a function of time in free fall.

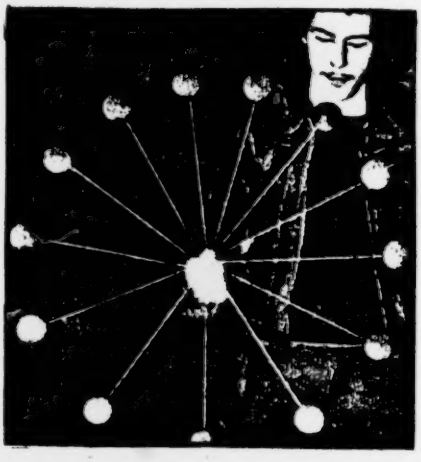


Figure 2.20. Stroboscopic photograph of a ball moving uniformly along a circular path.

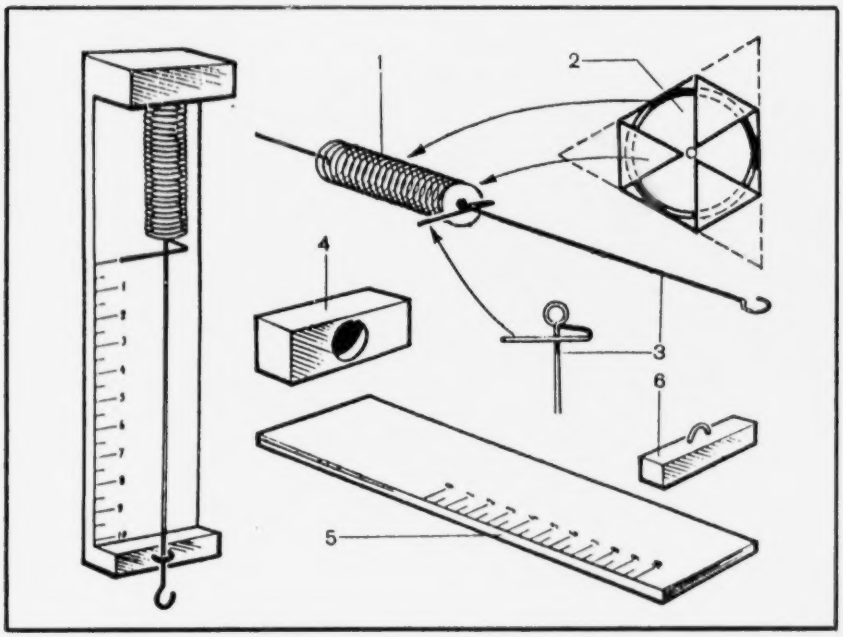


Figure 2.21. A home-made dynamometer.
1) spring; 2) sheetmetal bracket; 3) hook and pointer 4) upper retaining block
5) ruler; 6) lower retaining block.

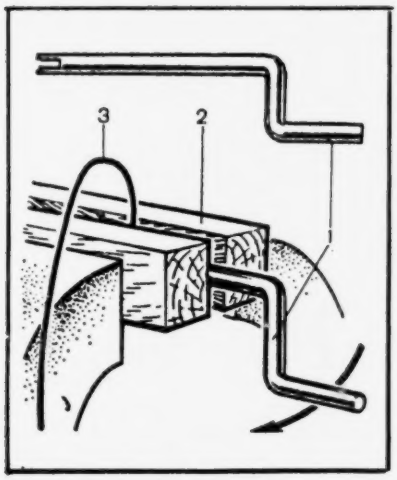


Figure 2.22. Device for making a spring out of a length of steel wire. 1) handle; 2) wooden blocks; 3) steel wire.

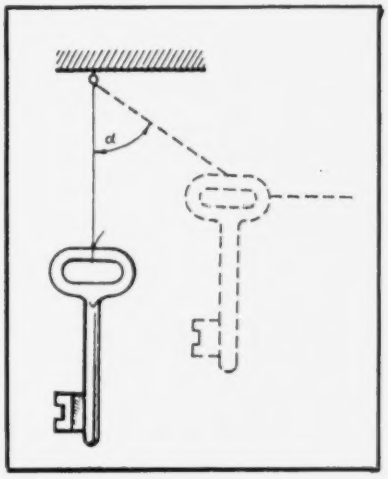


Figure 2.23. Illustration accompanying Problem 1.

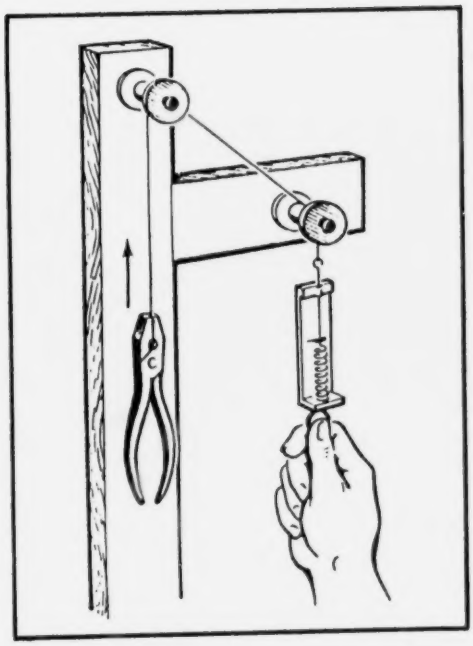


Figure 2.24. Illustration to accompany Problem 2.

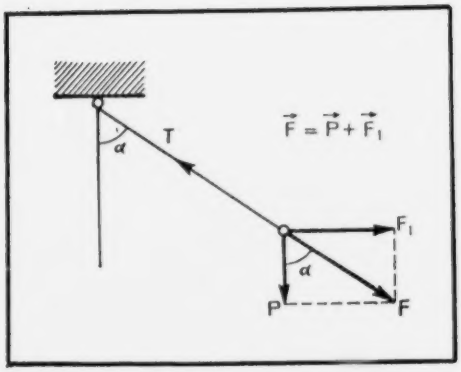


Figure 2.26. Illustration to accompany the solution to Problem 1.

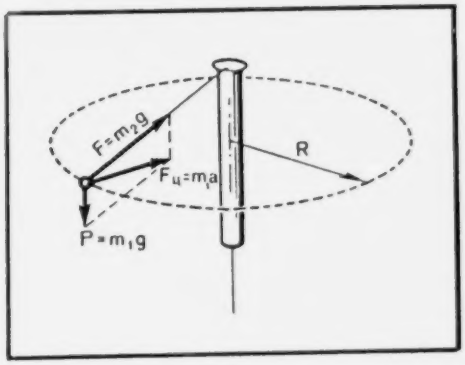


Figure 2.27. Illustration to accompany the solution to Problem 3.

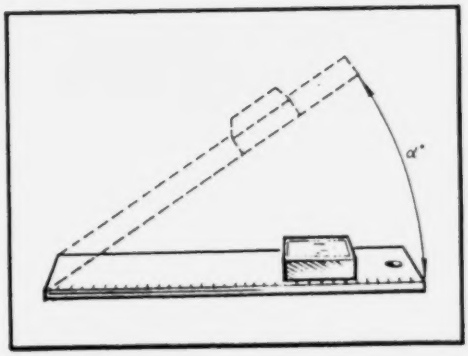


Figure 2.25. Illustration to accompany Problem 4.

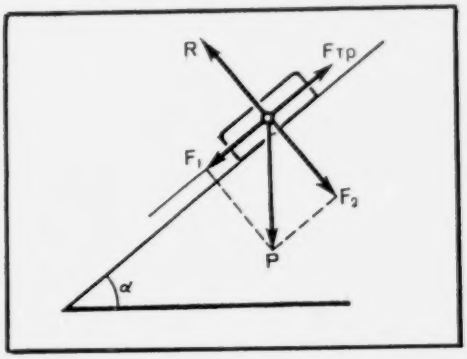


Figure 2.28. Illustration to accompany the solution to Problem 4.

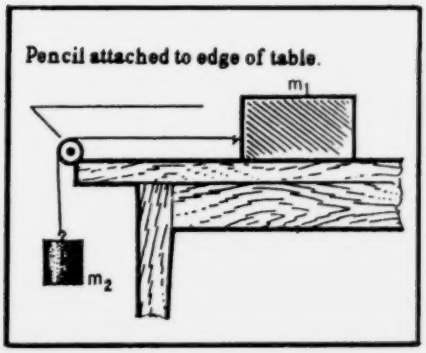


Figure 2.29. Illustration to accompany Problem 3.

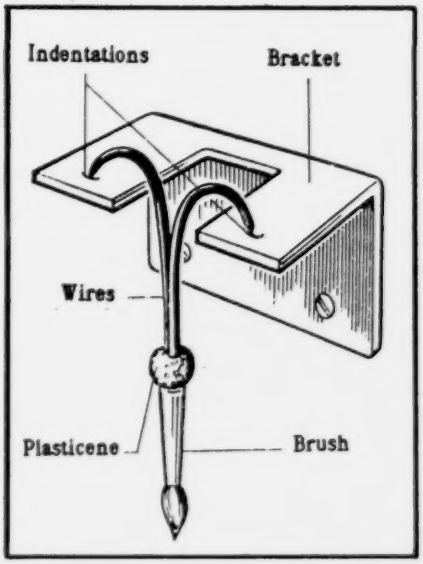


Figure 2.31. Simple device for marking equal time interval.

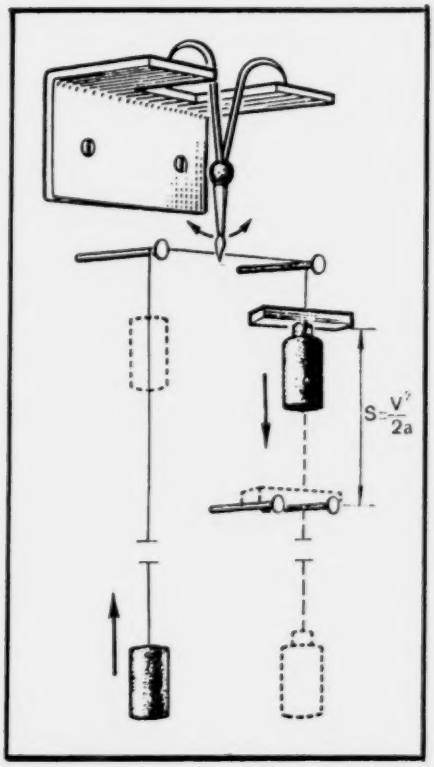


Figure 2.30. Device for launching a body so that it will move at a constant specified velocity.

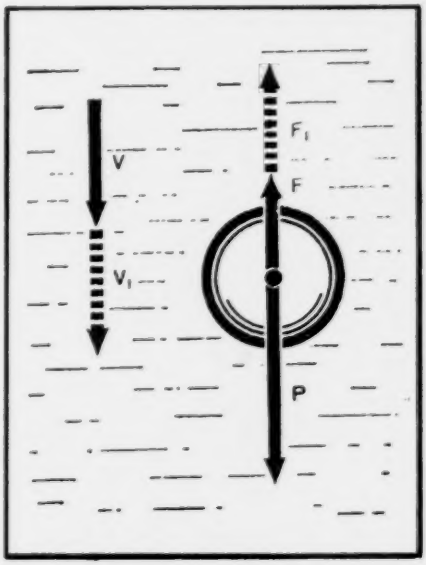


Figure 2.32. Diagram illustrating free fall at constant velocity.

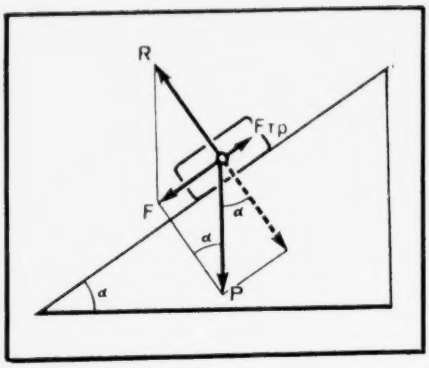


Figure 2.33. Diagram to illustrate the calculation of the angle of inclination of a plane required for launching a body with a specified acceleration.

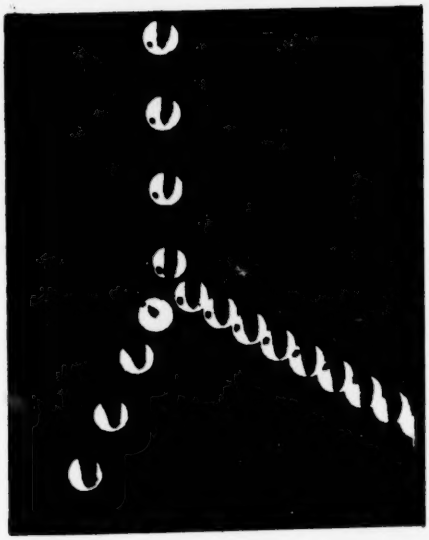


Figure 2.35. Elastic balls of equal mass move apart at right angles when they collide. This is a consequence of the conservation of momentum and kinetic energy.

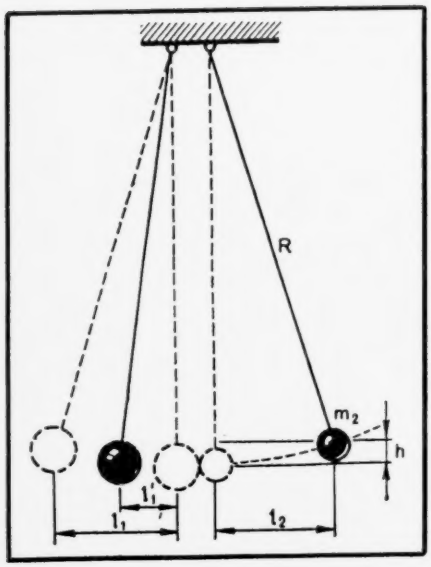


Figure 2.34. Collision of elastic balls.

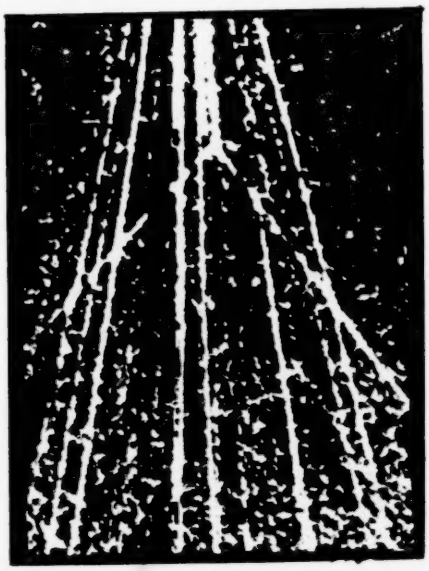


Figure 2.36. Photograph of the collision of two alpha particles.

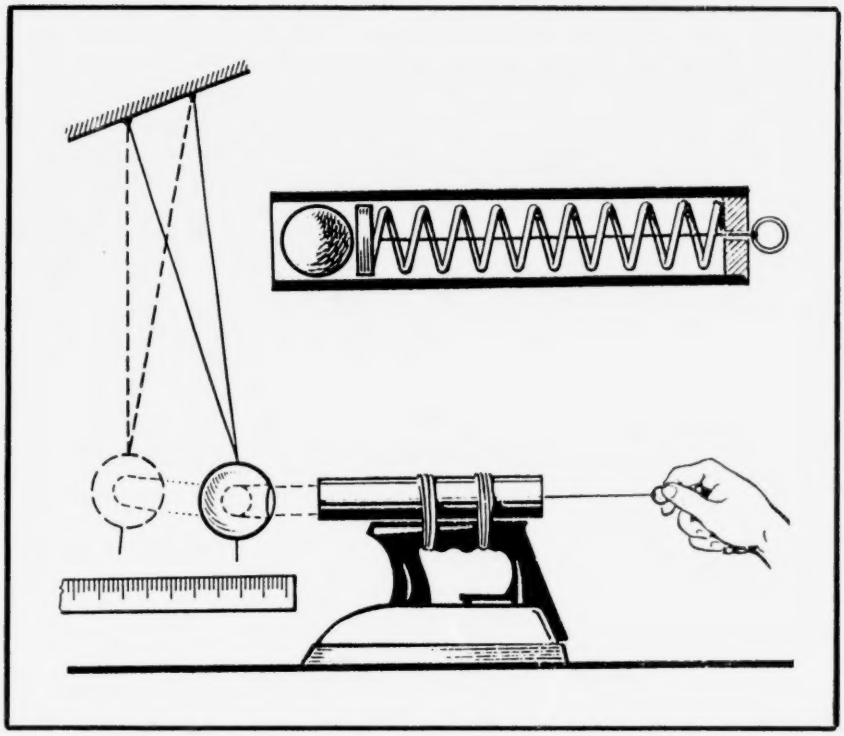


Figure 2.37
Home-made spring-loaded cannon.

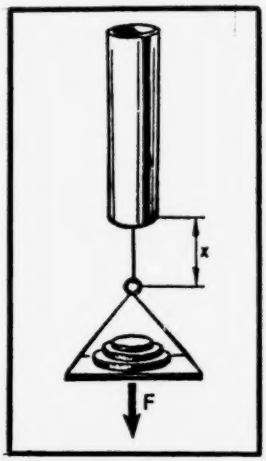


Figure 2.38 Determining the coefficient of rigidity of a spring.

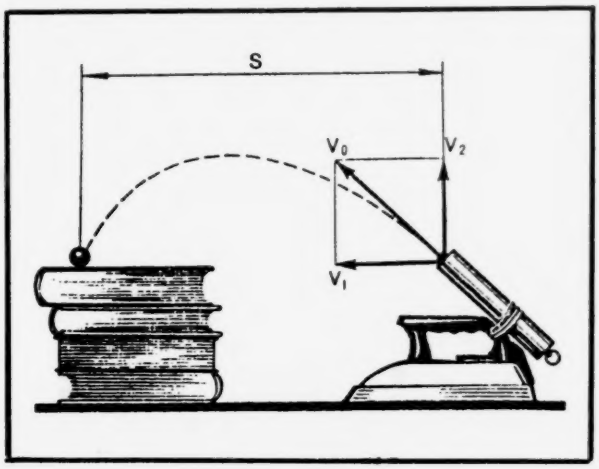


Figure 2.39 Firing a projectile to a fixed distance (range).

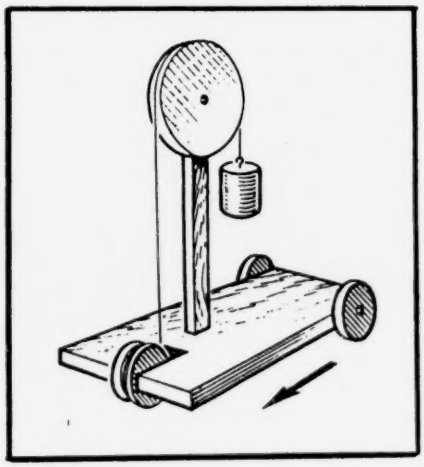


Figure 2.40. Illustration to accompany Assignment 4.

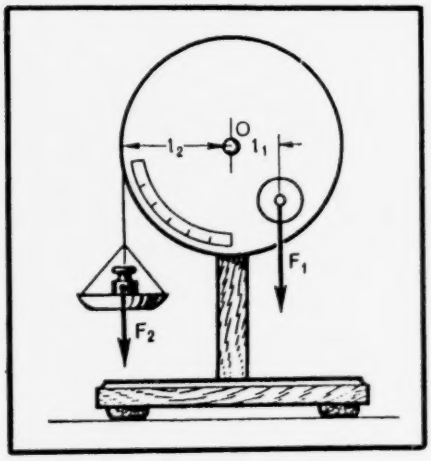


Figure 2.41. Illustration to accompany Assignment 5.

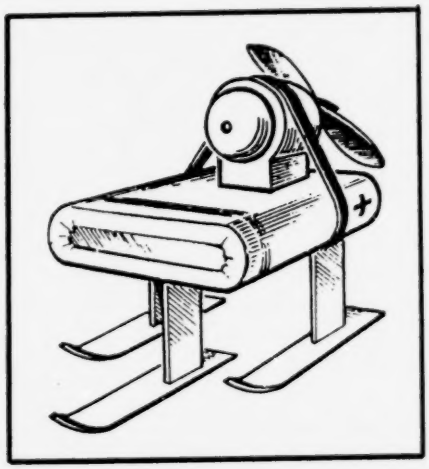


Figure 2.42. Possible design for a propeller-driven sledge.

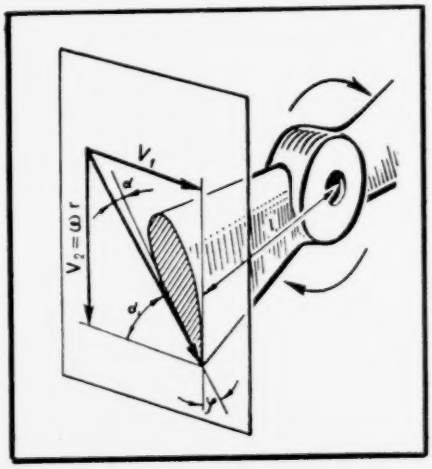


Figure 2.43. Diagram to accompany Assignment 6.

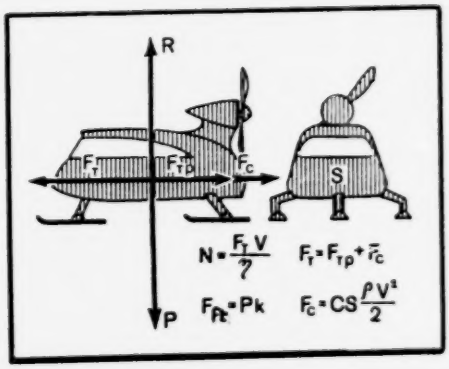


Figure 2.44. Schematic diagram for propeller-driven sledge design.

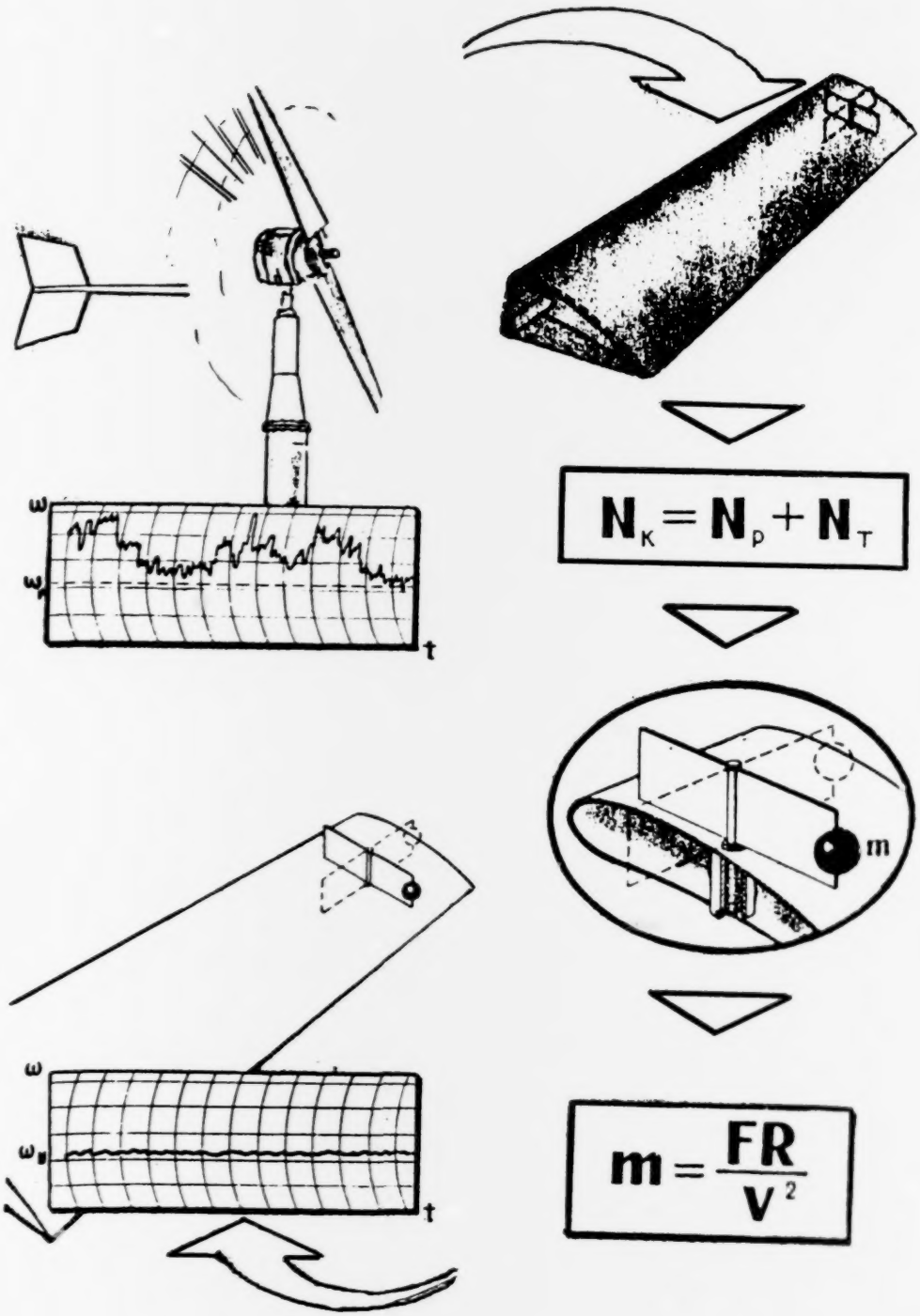


Figure 2.43

ANNOTATED BIBLIOGRAPHY

PHYSICS
Literature for the teacher

Programmy vos'miletnei i srednei shkoly. Fizika i astronomiya

(Curricula of the Eight-Year and Secondary Schools. Physics and Astronomy). Moscow, Prosveshchenie, 1982.

This is a normative document whose use by all general educational schools in the USSR is obligatory. It sets out the principal tasks and objectives of physics instruction in the secondary school, indicates the units and topics of the physics course for grades VI-X, and specifies the number of hours to be devoted to each unit. All of the sections of the curriculum contains information concerning intersubject links, front-of-classroom exercises, demonstration experiments, motion-picture films, and laboratory sessions. The latter part of the curriculum includes recommendations concerning field trips and visits, specifies basic requirements as to the practical skills to be acquired by pupils, sets out approximate grading standards, and supplies a list of literature helpful to the teacher.

Orekhov, V.P. and Usova, A.V. (eds.), Metodika prepodavaniya fiziki v 6-7 klassakh srednei shkoly (The Methodology of Physics Instruction in Grades VI and VII). Moscox, Prosveshchenie, 1976.

The book is designed to assist the teacher. It contains analyses of all topics stipulated in the curriculum and gives recommendations on the methodology to be used in the teaching of each. There are also recommendations of a general character on how to conduct a classroom discussion, how to implement the problem-solving approach to instruction and learning, how to perform a demonstration experiment in front of the class, how to solve problems, and how to conduct out-of-class exercises.

Orekhov, V.P. and Usova, A.V. (eds.), Metodika prepodavaniya fiziki v 8-10 klassakh srednei shkoly (The Methodology of Physics Instruction in Grades VIII-X). Moscow, Prosveshchenie, 1980 (Parts 1 and 2)

This is a practical guide for the teachers written in accordance with the current curriculum. Most of the book is taken up by specific recommendations on how to deal with the various topics of the physics course. It also contains advice on establishing intersubject links, and links between physics on the one hand and production and everyday life on the other. There are also helpful hints on how to solve problems and conduct physics experiments.

Pokrovskii, A.A. (ed.), Demonstratsionnyi eksperiment v srednei shkole (The Demonstration Experiment in the Secondary School). Moscow, Prosveshchenie, 1978 and 1979. (Parts 1 and 2)

The two parts of the book contain descriptions of all the demonstration experiments prescribed for the final three years (grades VIII-X) of secondary school in connection with the following units: mechanics, molecular physics, electrodynamics, oscillations and waves, optics and quantum physics. The experiments cover such topics as the action of centrifugal mechanisms, weightlessness, elastic and inelastic collisions, the life of an aircraft wing, Brownian motion, the Stern-Gerlach experiment, the temperature dependence of the resistance of metals and semiconductor, the motion of ions through an electrolyte, photoelectric relays, AC oscillograms, transformers, the transmission and reception of radio signals, the passage of light rays through lenses, interference, the diffraction and polarization of light, emission and absorption spectra, the photoelectric effect, the Rutherford experiment, the Wilson cloud chamber, ionized-particle counters, etc.

Pokrovskii, A.A. (ed.), Demonstratsionnye opyty po fizike v VI-VII klassakh srednei shkoly (Demonstration Experiments in Physics in Grades VI and VII). Moscow, Prosveshchenie, 1974.

The book contains decriptions of 169 experiments prescribed by the physics curriculum. The topics covered include the following: motion and forces, liquid and gas pressure, work and power, heat transfer and work, the aggregate states of matter, thermal engines, the structure of the atom, direct current, electrical power and work, electromagnetic phenomena. The book contains useful information concerning the conduct of demonstration experiments in the classroom (choice of experiments, demonstration requirements, experimental technique, experimental equipment, equipment required at the teacher's table, etc.).

Demkovich, V.P. and Demkovich, L.P., Sbornik zadach po fizike (A Collection of Physics Problems). Moscow, Prosveshchenie, 1980

The book contains over 1600 problems covering all aspects of physics. It also gives numerous rules relating to the use of approximation in the solution of problems. Answers to all of the problems are given at the end of the book. Some of the problems are accompanied by their detailed solutions.

Also included in the book are tables of the physical quantities which can be used in solving the problems (physical constants, densities of various substances, cofficients of friction, specific heat, heat of combustion, electrochemical equivalents, indexes of refraction, the periodic table of the elements, etc.).

Kamenetskii, S.E. and Orekhov, V.P., Metodika resheniya zadach v srednei shkole (The Methodology of Solving Physics Problems in the Secondary School). Moscow, Prosveshchenie, 1971.

The book presents the most important devices and techniques for dealing with qualitative, experimental, computational and graphic problems in secondary-school physics. Some general matters (the classification of problems, problem solving methods, types of assignments involving problem solving) are dealt with at the beginning of the book. This is followed by a series of typical secondary-school physics problems whose physical significance and solutions are set out in detail.

Multanovskii, V.V., Fizicheskie vzaimodeistviiy i kartina mira v shkol'nom kurse (Physical Interactions and the Picture of the World in the School Course). Moscow, Prosveshchenie, 1977.

Following in Heisenberg's footsteps, the author highlights the four fundamental theories of modern physics, namely classical mechanics, statistical physics, electrodynamics and quantum theory. In discussing these theories he demonstrates the possibility of constructing, for teaching purposes, a unified world picture whose essence would be a general interpretation of all of the aforementioned theories. Such an interpretation could be based on a hierarchy of distances and types of interaction. Thus, the principal role in the general picture thus constructed would be assigned to the concept of interaction.

Efimenko, V.F., Metodologicheskie voprosy shkol'nogo kursa fiziki (Methodological Aspects of the School Physics Course). Moscow, Pedagogika, 1976.

The book is designed as a methodological guide for teachers. It sets out the methodological content and philosophical significance of the basic concepts covered in the school physics course (e.g. matter, fields, mass, interaction, force). It also contains an account of the historical evolution of the physical picture of the world. The methodology to be followed in shaping a scientific world outlook in pupils is presented in relation to the main themes of the school physics course (mechanics, molecular physics, electrodynamics, optics, theory of relativity, nuclear physics).

Razumovskii, V.G., Razvitie tvorcheskikh sposobnostei uchashchikhsya v protsesse obucheniya fizike (Development of the Creative Abilities of Pupils Through the Study of Physics). Moscow, Prosveshchenie, 1975.

The book offers a psychological analysis of creative activities related to the study of physics. This is followed by a discussion of physics teaching methods from the standpoint of encouraging the development of pupils' creative abilities. The proposed methodology is based on the cycle of creativity in science in general: one proceeds from facts to a hypothesis, from the hypothesis to theoretical implications, and then to the practical application of such implications. What must be stressed in creative exercises is the intuitive aspect of inquiry, i.e. "educated guessing". It is in this light that the whole range of activities involved in the study of physics (assimilation of new material, problem solving, laboratory sessions, out-of-class assignments and homework) are discussed. The work includes a bibliography.

Razumovskii, V.G. et al. Fizika i nauchno-tekhnicheskii progress (Physics and Scientific-Technological Progress). Moscow, Prosveshchenie, 1980.

This book is intended to help the teacher make the physics course more interesting for the pupil by relating it to various aspects of progress in engineering and technology, namely mechanization, automation, the development of new materials, advances in the various technologies of shaping and treating materials, electrical power production, radioelectronics, radio engineering and optics. Each of these areas is linked in an organic way with the most important branches of physics. The book contains many specific examples which can be discussed in the classroom;

(Periodical;) Fizika v shkole (Physics in the School). Moscow, Pedagogika, 96 pages, Index : 71019.

Founded in 1934, this bimonthly periodical for secondary-school physics and astronomy teachers is published by the USSR Ministry of Education; Its most important sections are entitled "Physics and Engineering", "Pages from History", "Readers' Letters", "Teaching Methods", "Trading Experience", "Improving Lesson Effectiveness", "Intersubject Links", "In Our Schools", "Master Teachers", "Advanced-Level Courses", "Pedagogical Research", "Experiments", "New Teaching Aids", "Astronomy", "Out-of-Class Activities", "Problems and Questions", "What's New Abroad", "Reviews and Bibliography" and "Suggestions and Advice".

Each issue contains an index in Russian and in English.

Literature for the pupil

Peryshkin, A.V. and Rodina, N.A. N.A. Fizika, uchebnik dlya 6-7 klassov srednei shkoly (Physics, A Textbook for grades VI and VII). Moscow, Prosveshchenie, 1980

This textbook was written in accordance with the current curriculum and has been approved by the USSR Ministry of Education. It contains chapters on the following subjects: basic facts concerning the structure of matter, motion and forces, liquid and gas pressure, work and power, energy, heat transfer and work; changes in aggregate states, thermal engines, the structure of the atom; current, voltage and resistance; electrical power and work; eletromagnetic phenomena. The final sections contain answers to exercise problems, a description of laboratory work and a subject index.

The work has been awarded the USSR State Prize.

Kikoin, I.K. and Kikoin, A.K., Fizika, uchebnik dlya 8 klassa (Physics, A Textbook for Grade 8). Moscow, Prosveshchenie, 1982.

This textbook was written in accordance with the current curriculum and has been approved by the USSR Ministry of Education. It contains chapters on the following subjects: basic facts concerning motion; nonuniform rectilinear motion; curvilinear motion; the laws of motion; the forces of nature; the applications of the laws of motion; basic statics; the laws of conservation of momentum; mechanical

work and energy, the laws of conservation of energy. The final sections consist of a description of laboratory exercises, answers to exercise problems and a subject index.

Bukhovtsev, B.B., Klimantovich, Yu. L. and Myakishev, G. Ya., Fizika, uchebnik dlya 9 klassa (Physics, A Textbook for Grade IX). Moscow, Prosveshchenie, 1981.

This textbook was written in accordance with the current curriculum and has been approved by the USSR Ministry of Education. It contains chapters on the following subjects: basic molecular-kinetic energy theory, the laws of gases, the theory of an ideal gas, the change of a liquid into a gas and vice versa, surface tension, solids, electrostatics, direct current, electrical currents in various media, the magnetic field around a current-carrying conductor, and electromagnetic induction. The final section consists of a description of laboratory exercises, answers to exercise problems and a subject index.

Myakishev, G.Ya. and Bukhovtssev, B.B., Fizika, uchebnik dlya 10 klassa srdednei shkoly (Physics, A Textbook for Grade X). Moscow, Prosveshchenie, 1982.

This textbook was written in accordance with the current curriculum and has been approved by the USSR Ministry of Education. It contains chapters on the following subjects: mechanical oscillations and vibrations; electrical oscillations; the production, transmission and use of electrical energy; mechanical waves; electromagnetic waves; geometrical optics; light waves; the fundamentals of relativity theory; emissions and spectra; atomic physics; the physics of the atomic nucleus; elementary particles; the importance of physics in explaining the world and the development of the productive forces of society. Each chapter contains problems and exercises. The final sections of the book contain answers to exercise problems, a description of laboratory exercises and a subject index.

Rymkevich, A.P. and Rymkevich, P.A., Sbornik zadach po fizike dlya 8-10 klassov srednei shkoly (A Collection of Physics Problems for Grades VIII-X). Moscow, Prosveshchenie, 1980.

The book is designed for use by the pupil. It contains problems on all units of the physics curriculum, namely on motion in general; rectilinear motion, curvilinear motion and the laws of motion; natural forces, the application of the laws of motion; basic statics; conservation laws in mechanics; the principal applications of molecular-kinetic theory; the fundamentals of thermodynamics; the theory of an ideal gas; aggregate changes; electrostatics; direct current; electromagnetic phenomena; oscillations and waves; geometrical optics; light waves; basic relativity theory; radiation and light quanta; atomic and nuclear physics. The total number of problems is 1.249. The final sections consist of reference tables, answers to all problems and detailed solutions of some of the latter.

Enokhovich, A.S., Spravochnik po fizike i tekhnike. Posobie dlya uchashchikhsya (Handbook of Physics and Engineering. An Aid for Pupils). Moscow. Prosveshchenie, 1976.

This handbook was prepared with the contents of the school physics course specifically in mind. Following the units of the course, it contains reference tables of physical quantities (e.g. the specific resistance of semiconductors), technical characteristics of instruments (e.g. the power of various electrical devices), nomograms, physical characteristics of machines, mechanisms, animals and man (e.g. electrical parameters characteristic of the human organism). There is a subject index.

Kirillova, I.G. (compiler), Kniga dlya chteniya po fizike, 6-7 klass, posobid dlya uchashchikhsya (Physics Reader for Grades VI and VII, An Aid for the Pupil). Moscow, Prosveshchenie, 1978.

The book contains entertaining tables from the history of science, brief biographies of great physicists, description of interesting phenomena in nature and physics, descriptions of amusing experiments, and assignments suitable for pupils at the appropriate level. It is well illustrated.

Spasskii, B.I., Fizika v ee razvitii (Physics in its Development). Moscow, Prosveshchenie, 1979.

The book is concerned with the history of the basic branches of physics covered in the secondary school. It contains chapters on the following subjects: the development of mechanics, the development of the theory of heat, the development of the theory of electricity and magnetism, the development of optics. The final chapter is devoted to the history of modern physics and rehearses the origins of the theory of relativity and quantum physics.

(Periodical:) Kvant (Quantum). Moscow, Nauka, 64 pages. Index: 70465.

This is a popular science monthly aimed at secondary-school pupils. Created in 1970, this magazine is concerned basically with physics and mathematics. Its major sections are entitled "Scientists Address Young People", "Mathematics Circle", "Kvant's Puzzles and Problems", "Kvant and its Junior Readers", "Looking Through Your Textbooks", "The School Leaver's Practice Book", "Sample University and College Entrance Exams", "The Art of Computer Programming", "News Flashes" and Chess School".

The problems published in the magazine are accompanied by answers, hints and detailed solutions.

3.0. CHEMISTRY

3.1. The contents and structure of the chemistry course in Soviet schools.

Chemistry a required subject in Soviet secondary schols, is a course in basic inorganic chemistry (together with elements of general chemistry) and organic chemistry. In the modern, ten-year Soviet school, chemistry is offered in grades VII to X, taking up a total of 350 class hours (2 hours a week in grades VII and VIII, 3 hours a week in grades IX and X). Since complete secondary education is obligatory and universal in the Soviet Union, a solid general course in chemistry is something which all pupils take. This means that there is every justification for saying that there is universal chemistry education throughout the country.

The contents of the overall chemistry course can be set out in general terms by listing the topics included within the chemistry curriculum:

Grade VII	1.	Basic concepts of chemistry	-	22 hours
	2.	Oxygen. Oxides. Combustion	-	9 hours
	3.	Hydrogen. Acids. Salts	-	10 hours
	4.	Water. Solutions. Bases	-	19 hours
	5.	General information concerning the most important classes of inorganic compounds	-	6 hours
Grade VIII	1.	Review of the basic topics covered in Grade VII.	-	3 hours
	2.	Quantitative relations in chemistry	-	11 hours
	3.	The periodic law and Mendeleev's periodic table.	-	17 hours
	4.	Chemical bonds. The structure of substances	-	10 hours
	5.	Halogens	-	8 hours
	6.	The oxygen subgroup	-	10 hours
	7.	Basic laws of chemical reactions. Making sulfuric acid	-	7 hours
Grade IX	1.	Review of the basic topics covered in Grade VIII	-	4 hours
	2.	The theory of electrolytic dissociation	-	20 hours
	3.	The nitrogen subgroup	-	26 hours
	4.	The carbon subgroup	-	11 hours
	5.	The general properties of metals	-	8 hours
	6.	Metals belonging to the principal sub-groups of the periodic table	-	12 hours

	7.	Metals of the subsidiary subgroups of the periodic table	-	7 hours
	8.	Metallurgy	-	4 hours
	9.	Generalization of concepts mastered within the inorganic chemistry course	-	7 hours
Grade X	1.	Introduction to organic chemistry	-	1 hour
	2.	The theory of the chemical structure of organic compounds	-	3 hours
	3.	Saturated hydrocarbons	-	7 hours
	4.	Unsaturated hydrocarbns	-	12 hours
	5.	Aromatic hydrocarbons	-	6 hours
	6.	Natural sources of hydrcarbons and their refinement	-	4 hours
	7.	Alcohols and phenols	-	7 hours
	8.	Aldehydes and carbolic acids	-	10 hours
	9.	Esters. Fats	-	5 hours
	10.	Carbohydrates	-	9 hours
	11.	Amines. Amino acides. Proteins	-	8 hours
	12.	Generalization of knowledge acquired within the organic chemistry course	-	6 hours
	13.	Generalization of knowledge acquired within the course in inorganic and organic chemistry	-	21 hours

The present contents of the secondary schol chemistry course are the result of several successive reviews of the chemistry curriculum. Nevertheless, even though the specific contents of the chemistry course did undergo changes, its overall conception, under-lying ideas, and basic structure remained constant. The most thoroughgoing changes in educational subject matter were effected in the late 1960s and early 1970s, and then in the late 1970s and early 1980s. However, ever these major changes left intact the previous scope of the subject as a course in inorganic and organic chemistry.

Hence, prior to describing the new elements which have come into play in chemistry instruction, we shall set out briefly the reasons why the basic contents and structure of the subject of chemistry have remained largely unchanged.

Each review of the curriculum entailed a reconsideration and refocusing of the objectives of the school chemistry course, which naturally meant asking whether the given subject should continue to be structured as a system of knowledge concerning inorganic and organic chemistry, whether essential learning objectives could continue to be achieved within the context of such a course, and whether one ought not to consider a fundamentally new approach to the chemistry course.

Chemistry, as we all know, is concerned with the world of substances, their composition, their structure and their properties, as well as the transformation of one substance into another. Along with the other natural sciences, chemistry helps us to understand nature and to build up a scientifically sound picture of the world, thereby making a very important contribution to the general education of every young person. However, as is the case with the other sciences, chemistry is not simply a means of explaining the world: knowledge of its laws enables us to create new substances and materials, thereby promoting the polytechnically-oriented education of the pupil. This means that the study of chemistry as a science which enables us to understand the world around us on the one hand and as a productive force in the service of humanity on the other constitutes an essential component in raising the general educational level of pupils, helping them to shape a scientific world outlook and, at the same time, acquire practical knowledge and skills essential for future work in any number of fields. While it is directed at the achievement of specific educational goals, the study of chemistry is also an excellent means of helping youngsters to develop and mature intellectually.

As a result of the extremely intensive development of sciences in general, chemistry today constitutes a broad spectrum of subsidiary disciplines, each of which is concerned with a particular area of inquiry. These include inorganic and organic chemistry, physical chemistry and chemical physics, biochemistry and geochemistry, bio-organic and element-organic chemistry, radiochemistry and radiation chemistry, etc. Why is it then that inorganic and organic chemistry have been singled out for study in the secondary school? After all, these two disciplines are the earliest ones to have emerged in the history of this particular science, all of the other "chemistries' perhaps constituting a more faithful reflection of the present state of that science and deserving higher priority in the school curriculum.

Chemistry consists of the two basic conceptual systems: on the one hand, there is knowledge concerning substances, their composition, structure and properties; on the other, there is knowledge concerning processes, their laws and patterns and reaction mechanisms. Inorganic and organic chemistry were both built on as a system of knowledge concerning the chemical elements and the inorganic and organic substances into which they enter. In other words, the system which they constitute includes, in a subsidiary way, information concerning processes. Increasingly, the principal subjects of research in chemistry are chemical processes viewed as something which can be directed in a purposeful way, with successes achieved in studying the structure of substances in large measure serving the same purpose. This gives rise to the legitimate question as to whether the school chemistry course ought not to be structured not so much as a system of information concerning substances, but rather as a system of knowledge of chemical processes (their forms, laws and regularities, mechanisms, practical applications, etc.), with information concerning substances considered as a component subsidiary to such a system. Yet another problem must be taken into consideration. The foregoing list of study topics indicates that the structure of the secondary school chemistry course largely reflects the logic characterizing the historical development of the science of chemistry. In the introductory part of the course, the basic concepts of chemistry are dealt with on the basis of the classical automic-molecular paradigm; it is only later that they are taken up at the level of the periodic law and the structure of atoms, with the electron interpretation of chemical bonding being introduced at a still later stage, etc. With concepts presented in this way, the pupils gradually turn from phenomena as such to a consideration of their increasingly profound essence. Should this basic principle underlying the structure of the chemistry course be maintained in future? One possible answer would be that the chemistry course should, from the start, include the elements of electron theory, which could then be used to develop the subject, in line with the chemistry courses offered at university level today.

Let us set out, briefly, the arguments militating in favour of the present conception of the secondary school course in chemistry.

Notwithstanding the great variety of disciplines falling under the general heading of "chemistry", all of them are ultimately concerned with substances and processes. All substances are characterized by a single set of structural principles, while chemical processes are governed by general laws, with the broadest theoretical generalizations encompassing all "chemistries". For the purposes of the general educational course what needs to be selected out of the totality of knowledge about chemistry are those scientific facts, laws and theories which are most fundamental, extending to all fields of chemical knowledge, and whose mastery makes it possible to gain a grasp of the role of chemistry in building up a scientific picture of the world around us, in developing material production, and in opening up avenues towards the further development of the science in this or that direction. Such knowledge can be built up by studying inorganic and organic chemistry, disciplines within which information concerning substances is set out on the basis of the most general concepts, laws and theories available in chemistry.

The choice of structure under consideration can be justified in yet another way. The existence of two basic systems of knowledge - that of substances and that of proceses - obliges us to choose one or the other in structuring the subject matter or the course. The reason for choosing the former system is, we believe, self-evident. Without systematic knowledge concerning substances (their clasification, structure and properties), the study of chemical proceses becomes meaningless and a considerable penalty is paid in the pupil's ability to investigate the patterns involved in processes and in his understanding of their nature. Nor can such a course be well structured from the learning standpoint. On the other hand, as many years of experience have demonstrated, the study of substances is a sound way of presenting the necessary knowledge concerning processes. What is of cardinal importance is that the study of inorganic and organic chemistry is an exceptionally effective means of acquainting pupils with the applied aspect of chemistry, i.e. with the practical use of substances, the scientific principles underlying the major chemical industries and the major applications of chemistry in the national economy.

The inorganic chemistry course is based on the ideas of the periodic law and the periodic table of the chemical elements, for it is precisely through the knowledge of the elements and the compounds which they form that the pupil comes to understand the multiplicity of inorganic substances. Having performed the remarkable scientific feat of discovering the periodic law, Mendeleev at the same time provided us with a model of a chemistry course based on the principles of that law (his classical work entitled The Foundations of Chemistry). He begins by setting out the basic facts, concepts and laws of chemistry, describing typical elements and their compounds and discusses various natural groups of elements. All of this material is not only intrinsically important, but also serves as a basis for an understanding of the periodic law. This is followed by the presentation of the law itself, i.e., of the periodic table of the elements. The next section presents information concerning the chemical elements and their compounds by groups, an approach which amplifies, deepens and particularizes knowledge concerning the periodic table. This breakdown into preparatory, central and explanatory sections has become traditional in the school chemistry course, as is evident from the course curriculum presented above. Needless to say, the periodic law and the periodic table of the elements are dealt with on the basis of atomic structure.

Just as the inorganic chemistry course reflects by its contents the natural system of the elements and inorganic substances, the organic chemistry course is patterned according to the system (principal classes) of organic substances. The underlying structural principle here is the description of relatively simple substances (hydrocarbons), first, followed by the presentation of increasingly complex ones, all the way to those entering into living organisms and constituting the basis of their vital activity (carbohydrates, fats, proteins). The consecutive presentation of increasingly complicated but genetically related classes of compounds is apparent from the above course curriculum.

The history of chemistry instruction shows that the broadest and most fundamental theoretical generalizations sooner or later find their way into the school curriculum. Thus, information concerning atomic structure, the electron interpretation of chemical bonding, etc., all entered the school physics course soon after their discovery in science. Another pattern likewise emerged, that of presenting theoretical issues earlier and earlier in the course. For example, atomic theory was once relegated to the end of the chemistry course for grade VII, whereas today it is introduced in the very first chemistry lessons; Avogadro's law was taken up in grade X, whereas now it is studied in grade VIII, etc. This has led to an exaggerated tendency to saturate the course with theoretical notions and to introduce modern theories at the very beginning of the course. Here are some examples of suggestions tending the bring this about: since the periodic table constitutes the highest-level generalization of knowledge concerning the chemical elements, it is with the periodic table that the study of chemistry ought to commence; since the esential nature of the periodicity of properties of elements as well as the essence of chemical changes are linked with the electron structure of atoms, this means that the chemistry course ought, presumably, to be put on an electron-theory footing from the very start; why teach pupils to construct chemical formulae on the basis of the valence of elements if the notion of oxidation level is available or, again, why construct chemical equations using molecular formulae in those instances where reactions are of an ionic character? And so on. Our chemistry curriculum does not uphold such views.

In selecting theoretical material for inclusion in the school course, an important restriction is that such material must constitute something much more than pure information, i.e., that it perform an explanatory and predictive role in the learning process. When a course is overloaded with theories, opportunities for their careful consideration and application to facts are sharply curtailed, which means that the educational value of the theories is forfeited.

Theoretical issues cannot be included in a course without reference to what precedes them and to the basis on which they are introduced. New theories often cannot be understood unless the pupil has a grasp of that which gave rise to them in the first place. In other words, they must not supplant previous knowledge, but amplify it. For example, the periodic law and the periodic table cannot be properly understood without a prior grasp of such notions as those of simple and complex substances, chemical elements, the valence of elements, and the properties of those substances whereby elements can be described. The electronic structure of atoms and molecules cannot be understood without a grasp of the classical atomic-molecular theory and of the periodic table of the elements, etc.

As regards the presentation of theories increasingly early in the course, the following considerations must be borne in mind. If they are to become truly useful to the pupil, helping him to engage in creative activities, items of theoretical knowledge must be absorbed not dogmatically, but rather on the basis of proofs, including experimental proofs. It, therefore, seems to us that one should talk, not about the ***maximum*** but rather the ***optimum*** shifting of theoretical material to earlier parts of a course. It is indeed desirable to study theory as early as possible, but only provided that such theory is really needed by the pupil for understanding subject matter and that the appropriate conditions for conscious understanding have been met.

Another very important consideration is the following. Pupils spend four years studying chemistry. Over this period they are continually accumulating knowledge in all subjects and developing their intellectual faculties in general. While in grade VII they are unable to grasp chemistry with the same degree of depth as at later stages. At the same time, leaving material already covered without further amplification would be tantamount to a refusal to use the increased ability of pupils to approach that material in increasingly sophisticated ways. For this reason devoting such a lengthy period of time to the study of a given subject automatically requires that theoretical understanding be gradually deepened.

We might well ask whether structuring the chemistry course in several levels conforms to the didactic principle of scientific soundness at various course stages. The principle of scientific soundness does not necessarily imply complexity, merely that the treatment of the subject matter conforms to the basic theory and does not contradict scientific data. Although at the initial stages of the chemistry course chemical reactions are considered without reference to the ionic theory and the equations of reactions are constructed without ions being indicated, results cannot be considered a violation of the principle of scientific soundness. For example, the ordinary (non-ionic) equation of a reaction of a base with an acid should be considered valid, since it faithfully reflects the change in the composition of the substances involved as they react, as well as the quantitive relationships between these substances. The subsequent transition to equations written out in ionic form does not refute the previous interpretation, but rather brings to light certain new essential elements of the phenomenon.

Summing up, we can mention the following propositions as forming the basis for the selection of theoretical knowledge and its inclusion in the secondary school chemistry curriculum: a) the concepts and theories to be presented must be of the widest possible significance and applicable to all branches of chemistry; b) they must reflect major trends in the development of current scientific knowledge, but not necessarily be presented at state-of-the-art levels; c) by their place within the course, theories must reflect the most important stages in the development of scientific knowledge, thereby defining distinct and increasingly high theoretical levels in the study of the given subject; d) theoretical information is incorporated in the course as the need for it arises by virtue of the logical development of the subject matter, as and when the pupils become prepared for its conscious assimilation; e) in accordance with the role of theories in science, all new theoretical knowledge introduced must play the role of generalizing previously acquired knowledge, explaining facts and enabling the pupil to make predictions.

Without giving detailed consideration to the problem of selecting facts needed to describe substances and to investigate the theoretical issues of chemistry, we merely point out that this aspect of each subject is borne in mind in each successive review of the curriculum.

The selection criteria in this instance are as follows: a) any facts presented must reflect the principal characteristics of the substances under consideration, and also ensure the possibility of deductive proof and the verification of basic concepts, laws, and theories of chemistry; b) the facts must be suitable for demonstrating the explanatory and predictive functions of theory; c) there is a need for a specific (experimentally established) measure of facts to ensure the securing of knowledge in the pupil's mind and the development of his ability to apply that knowledge; d) facts must be used to demonstrate the significance of chemistry in modern life, in the development of chemical industries and in the constantly increasing use of chemicals in the national economy.

3.2. Principal trends in the improvement of the chemistry course

Bearing in mind the above positions of principle which underlie the structure of the school chemistry course, let us consider some of the principal lines followed in its modernization in the 1970s.

The need to improve the contents of the chemistry course was dictated by the requirements of scientific and technological advance and by the introduction of universal secondary education through the USSR. The increasing refinement and deepening of scientific knowledge and technological sophistication dictated the need for the improved preparation of school youngsters for life, work and further study. The successes of science made it possible to equip pupils with a more profound understanding of the laws of nature and their applications in material production. However, these opportunities were not being properly drawn upon given the levels of presentation of subject matter then prevailing.

Chemists had achieved remarkable successes in the study of the structure of substances, in understanding the interrelationship between properties and their structure, and in grasping the internal mechanisms involved in chemical changes. However, such knowledge was little used in investigating the material essence of chemical phenomena and their causal relationships, which certainly limited the contribution of the chemistry course to the education of school-age youngsters in a spirit of scientific materialism.

Chemists and chemical engineers had, by that time, established the general patterns and regularities involved in processes and the general principles of controlling such processes under industrial conditions. Once again, however, chemical industries were dealt with in the school in a fairly haphazard and all to discriptive manner, depriving pupils of knowledge concerning the general scientific foundations of modern production and diminishing their polytechnical preparedness.

The principal objective of the improvement of chemistry course contents therefore consisted in raising the theortical level of the subject, bringing it into line with modern scientific thinking as much as possible. Another purpose was to bring into greater relief the links between science, production and the day-to-day practice of Communist construction, thereby increasing the educational and personality-shaping function of the subject.

Since the study of the periodic law and periodic table contitutes a cardinal aspect of the inorganic chemistry course, we begin by noting the changes effected within this area. Experimental studies on chemistry instruction showed that the period required to lay the appropriate groundwork for the study of the periodic law could be reduced. This was done by eliminating from the initial portion of the course the descriptive material duplicating that presented in other natural science disciplines by defining in a more rigorous way the volume of knowledge required for grasping the periodic law, and in particular, information concerning the most important classes of inorganic compounds, as well as preliminary information concerning the natural groups of elements. This made it possible to shift the presentation of the periodic law and table from grade IX to grade VIII, this shift reflecting one of the general trends in the improvement of the chemistry course as described above.

Earlier coverage of the periodic law made it possible to incorporate the study of atomic structure and chemical bonding in the course, since pupils were now prepared to understand the regularities operating in atomic structures and the consequences of those regularities for the chemistry of the elements. All of this in itself served to raise the theoretical level of the course since it enabled all of the groups of chemical elements to be considered in the light of general scientific conception. The structure of the presentation of the periodic law was also reviewed. Previously, the periodic law was taken up in two "concentric" stages. In other words, it was initially treated in the classical way, after which the theory of atomic structure was presented, followed by a discussion of the present interpretation of the law and

and table. In order to avoid such concentricity it was suggested that study of the law begin with the theory of atomic structure, so that the periodicity of electron structures might be used to derive the periodicity in the changes in element properties i.e., that the modern interpretation of the law be presented immediately, circumventing the Mendeleev law and table stage in the development of chemistry. This proposal was not accepted, since it required the dogmatic introduction of knowledge fundamental to chemistry - something which could not be justified didactically. Moreover, the chemistry course, even in its early stages, was not merely a vehicle for transmitting scientific information to the pupil; it was also intended to show him how our knowledge concerning substances gradually deepened, in other words, how science advanced. Without doubt, this can be done more clearly and convincingly by presenting the periodic law from a historical-logical perspective. The periodic law is therefore considered, first and foremost, as a law of chemistry embodying certain scientific facts in a unified way, while the theory of atomic structure is something which is helpful in explaining it and penetrating the essence of established regularities just as was the case in science itself. Concentricity in the study of the subject is achieved by virtue of the fact that the school physics course as presently structured gives pupils a general notion of atomic structure, sometimes in advance of the chemistry course. This knowledge is immediately put to use to explain the physical meaning of the law as soon as the latter is derived from a comparison of the properties of elements, as to present the periodic table as soon as its structure has been demonstrated.

In accordance with the mainstream development of science, the main area where theoretical knowledge conveyed to the pupil has been deepened is that of the structure of substances. The periodic table has been used to present, in greater detail than previously, the structure of atoms: the pupil today learns about s- and p-electrons, electron clouds, electron pairing and the over-lapping of electron clouds when chemical bonds are formed. The notions of the eloctrone gravity of elements and oxidation level are introduced. Ionic, covalent and metallic bonding are dealt with in greater depth than formerly; the notion of donor-acceptor bond formation is presented. All of the forms of bonding are related to the corresponding types of crystal lattice, which makes it possible to present the dependence of the properties of substances on structure in a more convincing way.

In order to ensure deeper treatment of the theory of electrolytic dissociation (grade IX), the course includes an appropriate discussion of the mechanism of dilution in water of substances with different types of bonds. The electron-ion approach is then used to convey a general understanding of the basic types of reactions and the properties of inorganic substance belonging to the principal classes of such substances. An attempt to introduce protolytic theory into the inorganic chemistry course did not prove successful, since opportunities for using this theory in connection with the subject matter which followed were limited.

The theory of chemical processes received less amplification. Nevertheless, improvements were effected in the presentation of reaction rates, chemical equilibrium, and factors capable of increasing reaction rates and of shifting chemical equilibrium. Also discussed is the law of conservation of energy in chemical transformation, the thermal effects of reactions being related to the notion of a change in the supply of internal energy of substances and the strength of chemical bonds. The constraints inherent in a school course limit opportunities for a more profound consideration of the thermodynamic aspect of chemical reactions.

As before, the theoretical basis of the organic chemistry course is presented in terms of the classical structural theory developed by A.M. Butlerov, which deals with the order of combination of atoms within molecules and with the dependence of the properties of substances on that order. However, in accordance with the principal orientations of the subsequent development of that theory, it is complemented by stereochemical concepts and the theory the electron nature of chemical bonding.

The introduction of the elements of stereochemistry has as its purpose the shaping of more realistic notions concerning organic molecules and the amplification of the concept whereby the properties of substances depend upon their structure (geometric isomerism as illustrated by unsaturated compounds; the spatial structure of polymers, etc).

The introduction of electron theory makes it possible to demonstrate the structure of σ and π bonds and aromatic compounds in closer harmony with current notions, as well as to explain the mechanisms of certain reactions (substitution in saturated hydrocarbons, even-bond addition, polymerization), which makes it possible to safeguard pupils from the incorrect interpretation of chemical equations as expressions which might be thought of as reflecting the actual mechanisms of chemical transformations. The concept of the displacement of the electron density of chemical bonds and the induction effect makes it possible to demonstrate the material essence of atomic interaction within molecules and the dependence of chemical reactivity of substances on their structure.

In connection with the increased importance of chemistry in learning about various natural phenomena and the succeses achieved by molecular biology, more information is now provided concerning natural compounds (the structure of monosaccharides and polysaccharides, the primary, secondary and tertiary structure of proteins etc.)

The more profound knowledge of chemistry now acquired by pupils and their generally higher level of intellectual maturity make it possible to deal with organic substances in a more general way, shifting emphasis from a general consideration of specific representative substances (methane, ethylene, etc.) to a description of a homological series and class, followed by the discussion of individual representative compounds in the required terms on the basis of this general conceptual framework. Let us now consider the presentation within the secondary-school chemistry course of the other aspect of chemical science, namely its role in the development of material production. The presentation of this aspect constitutes one of the essential building blocks in polytechnical education.

As everyone knows, advances in science are finding their way into practice with increasing speed. Hence, they generate continuing changes in production, the master of new sources of raw materials, replacement of one process by another, more advanced process, and increased use of very general principles in the realization of various processes.

In accordance with the objective of polytechnical education, pupils must acquaint themselves with the general scientific principles underlying various chemical industries and the uses of chemistry in other branches of production. Just as the general concepts of chemistry, its laws and its theories, cannot be mastered without studying substances as part of a natural system, knowledge of the elements of production cannot be achieved without studying specific industrial chemical processes. Hence, the latter are selected in such a way that the study of individual processes helps bring to light their general underlying principles, assisting pupils to appreciate the fact that the chemical industries are one of the principal branches of production and to realize the importance of chemistry in the development of other areas of the national economy. The industries in question must be those which are most important to the economy of the country and which rely upon advanced engineering and technology. Moreover, the chemical principles on which these industries are based must be understandable to the pupil. The selection of chemical industries and proceses corresponding to the above objectives and requirements does not imply the introduction into the course of the study of additional substances apart from those necesary for imparting a grasp of the natural system and for developing scientific knowledge. In accordance with these criteria, the chemistry course affords ample scope for the study of such inorganic chemical industries as the production of sulfuric acid, ammonia and certain salts. The organic chemical

industries studied include the production of ethanol and various polymers. The significance of chemistry in other branches of the national economy is explained by means of ilustrations from the field of metallurgy (the production of pig iron, steel and aluminium), the building-materials industry (glass,cement), fossil fuel (petroleum, natural gas, coal) refinement, and agriculture (the use of fertilizers and pesticides).

In order to illustrate for the pupils' benefit the ways in which chemistry can be used to deal with major national economic problems without relegating information concerning industries to the role of illustrating the practical ignificance of chemical knowledge, the aforementioned industries are not scattered throughout the ntir course, but rather grouped into major study units. Thus, the chemistry course covers the production of fertilizers for agriculture (the study of the production of acids, ammonia and salts is grouped under this unit), metallurgy (ferrous and nonferrous) and the refinement of combustible fossil fuels.

We are at present witnessing a rise in the role of polytechnical education in the occupational counselling of pupils with a view to preparing them for a working life. Hence, the presentation of chemical industries and the role of chemistry in various branches of the national economy in general involves consideration not only of the principls of chemistry and chemical engineering and technology, but also the roles of various people working in the chemical industry such as technicians, operators, laboratory personnel and others. The role of the intellectual component in their activities within the context of present-day mechanized and automated production is stressed along with the role of scientific knowledge in mastering one's occupation and in improving one's qualifications.

3.3. Some special methodological features of the chemistry course

Ensuring the all-around development and sound polytechnical training of pupils means seeing to it that they acquire a sound grasp of scientific knowledge.

One prerequisite for the mastery of course material is a good grasp of previously acquired knowledge required for its proper understanding. For example, a pupil who has not understood the concept of valence, does not know the characteristic properties of base and acid oxides, and those of bases and acides cannot possibly hope to master the periodic law; one who is not familiar with the electron structure of atoms and the forms of chemical bonding will have difficulty in studying the theory of electrolytic dissociation; a pupil who is unable to distinguish between and bonds in organic chemistry will not be able to gain insight into electron shifts and their influence on the properties of substance. For this reason the chemistry curriculum, in addition to listing the topics included within each general subject area clearly set out grade by grade the syllabus of basic knowledge which each paper is required to master. Many teachers present a given course topic only after they have made sure that such mastery has been achieved by all pupils in their class.

For example, the requirements for pupils in grade VII include the following:

Knowledge of the basic proposition of atomic-molecular theory; the ability to state and apply the following concepts in the light of that theory: relative atomic and relative molecular mass, mixtures, simple and complex substances, chemical elements, valence, oxides, bases, acides, salts and types of reactions (decomposition, combination, substitution, exchange); the ability to formulate and apply the law of conservation of mass; knowledge of the chemical symbols of the elements, and of the meaning of chemical formulae and equations; knowledge of the composition of oxides, bases, acides and salts. Understanding of the relationship between the composition of a substance and its properties and uses.

The study of organic chemistry in grade VII requires the following background knowledge:

Familiarity with the basic proposition of the theory of chemical structure of substances, the phenomenon of homology, structural and geometric isomerism, the major functional groups of organic substances, types of bonds (simple, double, triple, aromatic, hydrogen), their character in terms of electron theory, and their effect on the properties of substances; understanding of the meaning of the structural and electron formulae for organic substances, methods of representing structural and geometric isomers, and shifts in electron density in molecules. Familiarity with the most important representatives of classes of organic compounds, the structure of their molecules, their properties, and their genetic relationships with other compounds, as well as their significance in the national economy; familiarity with specific plastics, rubbers and chemical fibres.

As experience shows, the timely grasp of basic background knowledge by the pupil plays a major role in developing and maintaining a lively interest in a given subject, since the mind of such a pupil is always ready to absorb new material. On the other hand, when a pupil has not managed to acquire such background knowledge in good time, his interest invariably flags and his ability to fully grasp new information is forfeited.

One important consideration in ensuring the conscientious mastery of topics in chemistry is that of proving statements and justifying newly presented information, since knowledge acquired in a dogmatic way is knowledge which is grasped prefunctorily and which can readily prove inadequate when an attempt is made to apply it. It is particularly important that pupils acquire theoretical knowledge along with all of the necessary proofs thus becoming convinced of the objective significance of that knowledge. "Recognition of the fact that theory is a photograph, an approximate copy of reality," wrote V. I. Lenin, "is the very essence of materialism". (Complete Works, Vol. 18, p. 281).

Provability can be demonstrated in various ways. In the study of classical atomistics, it means drawing upon information from the history of chemistry. In the presentation of the law of conservation of mass and other basic concepts of chemistry, it entails inductive reasoning on the basis of known facts and experimental findings. In discussing the electron structure of atoms, one can rely on the periodic table of the elements and on the properties of substances. In examining the theory of the structure of functional groups of organic compounds, reliance can be placed on chemistry experiments. And so on.

For example, in investigating the functional group of alcohols, some amount of ethanol is made to react with metallic sodium with a view to measuring the volume of hydrogen released in the reaction. Calculations are then carried out to show that each molecule undergoes the replacement of one of its hydrogen atoms by sodium. Knowing the molecular formula for alcohol, one can conclude that this atom of hydrogen was present in the molecule in a special state, so that if a specific valence is maintained among the elements, it is clearly bonded to the carbon atoms through oxygen.

By following the principle of provability, it is possible to convey throughout the entire chemistry course the theoretically and practically important notion of the interdependence of the structure, properties and practical applications of substances. Pupils become convinced, for example, that the characteristic properties of acids are related to the splitting off of a proton, which property determines this or that practical application of such a substance; the properties of certain solids can be explained in terms of the type of crystal lattice involved (ionic, atomic, molecular, metallic), which in turn determines the practical uses of the given substance; pupils are already aware of the way in which the chain structure of polymers effects their properties and how these properties can be used in creating various materials.

It is with the same aim of ensuring the provability of knowledge as well as of rendering it more profound that the school chemistry curriculum is oriented towards the demonstration of intersubject links.

The place of chemistry in the family of sciences is between physics and biology. The explanation of chemical laws is, however, based largely on the laws of physics. For this reason, the successful study of chemistry in the school is predicted on its presentation hand-in-hand with physics.

The school chemistry course is also related to other subjects, namely biology, economic geography, mathematics, and to some extent the humanities.

The chemistry curriculum provides the teacher with an indication as to which major items of knowledge from other subject areas must be drawn upon as reference materials in covering a given topic.

Thus, the presentation of the very first course unit entitled "Basic concepts of chemistry", which is concerned with atomic-molecular theory as the first theoretical level of the course, requires turning to such concepts of physics already familiar to the pupil as those of a body, a substance, an atom, a molecule, the molecular structure of solids, liquids and gases, the mass of a substance, and internal energy. In covering the unit "Oxygen. Oxide. Combustion." the teacher points out the need for drawing upon information from botany (plant respiration), physics (the notion of density, the aggregate state of matter, the amount of heat, and the heat released in combustion), and geography (the atmosphere, air pollution control). When the periodic law and chemical bonding are taken up in grade VIII, necessary reference is made to such concepts as those of the electron, the atomic nucleus, the ion, the two types of charges, the interaction of charged bodies and the electric field. The study of fats, carbohydrates and proteins within the organic chemistry course is supported by information from the biology course and on the biological role of substances.

photosynthesis, the structure of protein molecules and enzymes. In those instances where units relate to various chemical industries, the curriculum calls for reference to information drawn from economic geography concerning the nature of the corresponding sectors of the national economy, the sources of raw materials, and the location of the appropriate industrial plant over the territory of the USSR.

Unfortunately, not enough use is being made of pupils' mathematical knowledge in the study of chemistry. The traditional way of applying mathematics was to solve chemistry problems using a relatively uncomplicated range of mathematical techniques. At the present time efforts are being made to develop ways of using mathematical knowledge in the presentation of basic course material, laws and various kinds of functional relationships. This certainly imparts a greater degree of provability to solutions and raises the level of generality of the knowledge acquired.

The chemistry course in turn provides knowledge which is needed in the study of other subjects. As far as the physics course is concerned, for example, it affords information concerning simple and complex substances, the periodic law, the structure of the electron shells of atoms, the electron nature of chemical chemical bonds, semiconductors, polymers, etc. It also supplies some very important information to the biology students including, the notion of elements, the building up of molecules out of atoms, the nature of chemical changes, oxidation-reduction processes, the circulation of elements in nature, fertilizers, the structure and properties of organic substances, etc This category of knowledge is not set apart within the chemistry curriculum, on the other hand, such borrowings from chemistry are pointed out in the syllabi for the relevant subjects.

Intersubject links are presently viewed not simply as a matter of drawing upon knowledge from other subjects, but rather as one of using the means afforded by various disciplines to develop concepts common to these disciplines (for example, the notion of a substance, the levels of its organization, the general laws of motion, etc.), thereby helping to shape a general scientific world picture in the mind of the pupil.

In order to activate learning on the part of the young person, as well as to develop independent knowledge acquisition and creative research faculties, increasing emphasis in the school chemistry course is being placed on the problem-oriented structuring of lessons and assignments. The earmarks of problem-oriented learning are the frequent confrontation of the pupil with a problem-solving situation involving difficulties which prepare the ground for acquiring new knowledge and contradictions whose resolution requires either new knowledge or else a new approach to learning. The desire to overcome such hurdles, to find an answer to an unsolved question is the best possible way of mobilizing the reasoning abilities of the pupil.

Among the various ways of setting up problem-solving situations designed to promote active thinking by the pupil is to ask questions which are, so to speak, inherent in the subject matter itself. A chemistry course structured according to the principle of concept evolution thus reflects in some considerable measure the historical logic whereby knowledge about chemistry was built up, thus presenting the science as something dynamic rather than as a body of "final" truths. But the development of science, as with any developmental process proceeds via contradictions and their resolution, which is why it is natural for contradictions to arise during the learning process itself. The pupil is simply required to surmount these on his way to finding the right answer. This can be illustrated by an example concerning the periodic law. As already noted, this law is first approached according to Mendeleev and interpreted as the periodic dependence of the properties of elements on their atomic mass. As they proceed with their study of the succession of elements, pupils eventually run into violations of this dependence in the case of the pairs *Ar* and *K*; *Co* and *Ni*; *Te* and *I*. This confronts them with the need to find the reason for these inconsistencies and thus to gain a better understanding of the nature of elements. The quest for an answer naturally leads them to investigate

the structure of atoms more deeply and to establish a more sophisticated connection between the properties of elements and the charge carried by their atomic nucleus. Historical logic is violated in the structure of the unit in question, for following that logic would mean starting on the structure of atoms with the "derivation" of the periodic law on the basis of dogmatically posited electron structures. This is an approach which gives rise to no problems whatever, and all the pupils need to do is to memorize the required propositions.

The level of independent thinking exercised by pupils in resolving contradictions can vary depending upon preparation. In certain instances the teacher will show how the learning problem which has arisen can be dealt with; in other cases, the same result is achieved vie heuristic discussion, after which the pupil who is sufficiently well prepared can take hold of the required item of knowledge by himself.

The problem-solving situations most typical of the chemistry course involve contradictions between:

1) theoretical notions familiar to the pupil and new facts (for example, pupils know that the properties of substances depend upon their composition, but the organic chemistry course teaches them about cases where different properties are exhibited by substances with one and the same composition; the resolution of this contradiction results in deeper insight into isomerism);

2) known facts and new theoretical knowledge (pupils are aware that carbon is a tetravelent element, but when they become familiar with the electron structure of its atom, they discover that it has only two unpaired electrons capable of forming chemical bonds; the resolution of this contradiction gives rise to the notion of an excited atom and the hybridization hypothesis);

3) an implication or implications of a theory on the one hand and observed experimental results on the other (on the basis of the ordinary strucural formula of benzene, one may conclude that this substance exhibits the reactions of an unsaturated hycrocarbon, but experiment does not confirm such an assumption; the contradiction leads to a closer examination of the electron structure of the benzene molecule);

4) different consequences of differing theories (in accordance with the theory of structure, two different structural formulae for ethanol can be derived; it is clear, however, that only one of them can possible correspond to a given substance; the resolution of the contradiction with the aid of experimental findings produces the required answer);

5) facts at variance with one another familiar to the pupil (substances belonging to the same homological series are characterized by certain common properties, but the first term of the series usually has some distinctive characteristics; the pupil learn that steel is obtained from pig iron by "burning out" certain impurities, but more steel is produced in the country than pig iron). One could go on to mention numerous other contradictions which give rise to problematic situations in the study of chemistry.

In those instances where the problems which arise become particularly significant from the learning standpoint while the pupil has no means of finding the answer by himself, the latter may be sought in the chemistry textbook.

For example, let us cite a passage from an organic chemistry textbook concerning the electron structure of the methane molecule. From the inorganic chemistry course the pupil knows that carbon is tetravalent; he also knows the structural formula for methane and is aware of the fact that the chemical bonds entered into by its molecule involve electron pairs common to different atoms. The textbook then goes on to say the following:

"When the theory of the three-dimensional structure of molecules began to emerge in organic chemistry, it turned out that the methane molecule was actually tetrahedral rather than flat, as can be shown on paper (Figure 3.1).

Why is the methane molecule tetrahedral? Clearly, we must proceed on the basis of the structure of the carbon atom. But here we run into a contradiction. The carbon atom has four valent electrons, two of which are paired s-electron which cannot form chemical bonds with hydrogen atoms. Chemical bonds can be entered into by the two unpaired p-electrons alone. But then the methane molecule would have to have the formula CH_2 rather than CH_4, which is certainly not the case.

This seeming contradiction is resolved by the following interpretation of chemical bond formation:

When a carbon atom interacts with hydrogen atoms, the s-electron of its outer shell pair off: one of them takes up the vacant position of the third p-electron, moving in a three-dimensional figure-of-eight pattern (cloud) perpendicular to the clouds of the two other p-electrons. The atom is then said to have passed into the excited state. Now all four of the valent electrons have become unpaired and capable of forming four chemical bonds.

But now a new contradiction arises. The three p-electrons must form three chemical bonds with hydrogen atoms alng mutually perpendicular directions, i.e., at angles of 90°, while a fourth hydrogen atom could be bound in an arbitrary direction, since the cloud of the s-electron is of spherical shape (which means that the bonds in question would differ in their properties). We know, however, that all of the C-H bonds in the methane molecule are entirely similar and form angles of 109°28'. The seeming contradiction which arises can be resolved by applying the concept of electron hybridization.

In the process of chemical bond formation, the clouds of all three of the valence electrons of the hydrogen atom (one s- and three p-electrons) become uniform (Figure 3.2). All of them assume asymmetrical figure-of-eight shapes elongated in the direction of the vertices of the tetrahedron (the asymmetrical distribution of electron density means that the probability of an electron being situated to one side of the nucleus is greater than that of its being situated on the other side).

The angle between the axes of the hybrid electron clouds turns out to be equal to 109°28', which enables them as similarly charged clouds to draw a maximum distance apart from one another. As they are elongated towards the vertices of the tetrahedron, such clouds are subject to a considerable overlap with the electron clouds of the hydrogen atoms, which results in the release of large amounts of energy and the formation of strong chemical bonds with similar properties (Figure 3.3A).

Hybridization can extend to various members of electrons in the atom. In the case under consideration, hybridization involves one s-electron and three p-electrons. This type is called sp^3 - hybridization.

The tetrahedral shape of the methane molecule is therefore due to the tetrahedral orientation of the four hybrid electron clouds of the carbon atom in this compound.

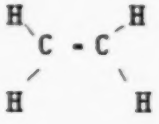
Since the electrons involved in the covalent bond forms cloud which are common to the bonded atoms and envelope both nuclei, the electron structure of the methane molecule can be represented as shown in Figure 3.3B".

The problem-oriented approach used in the textbook can be further illustrated by quoting its treatment of the structure of ethylene (ethane). The reason for the apparent violation of the tetravalence of carbon in the ethane molecule C_2H_6 has already been investigated: the tetravalence is in fact maintained, since the carbon atoms are interconnected. On the basis of empirical data the textbook derives the molecular formula for ethylene C_2H_4. The explanation then continues:

"But we then run up against a contradication. The carbon atoms in the ethylene molecule are connected with a lesser number of hydrogen atoms than is the case with the methane molecule. How then can the carbon remain tetravalent? In order to answer this question, let us examine the structure of the substance.

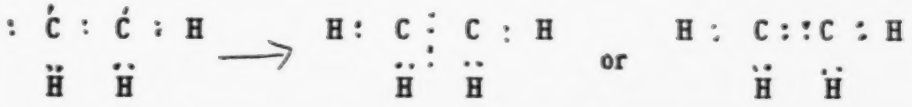
It has been established that the ethylene molecule is bonded to two hydrogen atoms. Denoting the bonds between atoms in the molecule by dashes as was done previously, we obtain the formula H - C - C - H.

It is clear that this representation does not express the structure of the ethylene molecule. The fourth valences of the carbon atom cannot remain free, and indeed they are connected with one another, forming a second bond between the carbon atoms:



In dealing with hydrocarbons thus far, we have encountered only simple or ordinary chemical bonding between atoms. The ethylene molecule presents us with a case of double bonding.

Since each valence of the carbon atom is associated with the presence of an unpaired electron in its outer electrol shell, the formation of a double bond between the carbon atoms clearly entails the formation of a second electron pair common to the two atoms:



Thus, the tetravalence of carbon and the octet rule for its atoms are maintained in the ethylene molecule. Each valence line in the structural formula represents a single pair of electrons as before.

The following should be noted, however. We have been assuming so far that the valence electrons of the carbon atom form chemical bonds in the direction leading from the centre of the atom to the vertices of the tetrahedron. In the present instance, on the other hand, the bonds are oriented in a single direction, i.e. along the line connecting the centres of the carbon atoms. In order to see whether this is really the case, let us consider in more detail the way in which electrons interact when a double bond is formed.

Physical experiments have shown that in contrast to the hydrocarbons considered previously, the nuclei of all the atoms in the ethylene molecule lie in a single plane, while the valence angles in the molecule are not 109°28', but rather 120° (Figure 3.4).

Such a structure cannot be explained on the basis of the familiar notion of sp^3-hybridization associated with the tetrahedral structure of the methane molecule. Hybridization in this case involves only three of the four electron clouds of the excited carbon atom, namely those three which are necessary for establishing bonds with three atoms (one s-electron cloud and two p-electron clouds). What we have therefore, is sp^2 - hybridization. The hybrid clouds have a similar shape - that of elongated three-dimensional figures-of-eight. In forming chemical bonds, these clouds, as in the case of methane, move the maximum possible distance apart from one another (why?). This maximum distance corresponds to an angle of 120° between these axes.

But each of the carbon atoms has one p-electron left over. The cloud of this electron is not involved in hybridization, its shape has not changed and continues to be that of a three dimensional figure-of-eight with a uniform distribution of the electron density to either side of the nucleus. The axes of these electron clouds are perpendicular to the plane of the atomic nuclei, since they are then at the furthest distance from the electron clouds already involved in forming the chemical bonds. These electron clouds in the shape of three-dimensional figures-of-eight partly overlap above and below the plane of the atomic nuclei, thereby forming a second bond between the carbon atoms (Figure 3.5A).

However, such lateral overlapping of the electron clouds is less significant than that of the clouds interacting along the straight line connecting the centres of the atoms; Moreover, the overlapping occurs at a greater distance from these centres. For this reason, the second bond in ethylene is weaker than the first bond. Nevertheless, once it is established, the atoms draw still closer to one another: in the ethane molecule the distance between the atomic nuclii is 0.154 nm, whereas in the ethylene molecule it is 0.134 nm.

The first and stronger of the bonds formed due to the overlapping of the electron clouds in the direction of the straight line connecting the atom centres is called the σ- sigma bond; the second (weaker) bond associated with the overlap of electron clouds outside the plane of the atomic nuclii is referred to as the π-pi-bond. The usual covalent bonds joining carbon atoms to hydrogen atoms are likewise σ bonds.

The electrons entering into a π -bond, just as those involved in σ -bonding, cease to belong to a particular atom. They now belong to both of the carbon atoms, forming a common cloud whose electron density is equally distributed above and below the plane of σ -bonds (Figure 3.5B)."

The problem-oriented approach is widely used in studying chemical industries. This serves to heighten pupil interest in applied chemistry and to develop creative abilities in preparation for a working life.

The general approach to the study industrial processes is as follows: Once the composition, structure and properties of a given substance of practical importance are known there arises the problem of its industrial production. This means that one has to consider sources of raw materials and the physical-chemical principles underlying the production process. This serves as a basis for identifying optimal conditions for the required reactions, for a brief description of the technological processes involved, and for a consideration of the functions of personnel involved in implementing the processes. Reliance upon physical-chemical principles enables pupils to gain insight into the nature of production and the ways in which production is regulated and controlled. Problem-solving situations in this context are of a somewhat different character, and do not always involve contradictions. Let us consider, for example, how the problem-oriented approach is helpful in the study of sulfuric acid production.

In covering previous study units, pupils have become familiar with the composition, the physical and chemical properties of sulfuric acid, and its uses. They are now provided with information concerning the scale and plans for the future development of sulfuric acid production in the country. The following problems now arises: what do we need in order to produce sulfuric acid in such tremendous quantities? At this juncture the pupils recall previously presented data concerning the occurence of sulfur and sulfur-containing raw materials (sulfide, sulphates) in nature.

They then learn that the roasting of sulfide ores generates considerable quantities of sulfur dioxide. Similarly, the refinement of natural gas and petroleum yields hydrogen sulfide as a by-product. Is it not possible to put these gases to use?

Discussion of the problem of raw materials leads the pupils to the conclusion that under differing conditions, a chemical product can be obtained from various raw materials. They then set about constructing equations of reactions involved in obtaining sulfuric acid from sulfur, sulfur dioxide, hydrogen sulfide and iron pyrite. This is followed by an examination of one of the methods of obtaining sulfuric acid, such as the process based on the use of iron pyrite.

The pupils are thus confronted with the task of choosing those process conditions which will ensure the most efficient use of the raw materials and the most rapid product output. In the foregoing example, they would be called upon to investigate ways of ensuring the maximum efficiency and productivity of iron pyrite roasting kilns. Knowledge of reactions and the conditions which influence reaction rates enables pupils to choose the required temperature and to recognize the need for the maximum exposure of reacting surfaces (roasting in a "boiling layer") and to look into the possible use of oxygen (instead of air) for the same purpose.

The next problem to be tackled is that of a reactor in which such conditions might be achieved. Once again, the pupil is asked to apply his reasoning skills in establishing a suitable roasting kiln design. Should the apparatus operate periodically or continuously? How can the iron pyrite and air be delivered? How is the temperature regulated? What can be done with the heat release during the reaction? And so on. In thinking about and discussing a sequence of such questions, a pupil produces a kind of mental design of the required reactor (roasting kiln).

The same sort of problem orientation is applied to determining the optimal conditions for transforming sulfur dioxide into sulfur trioxide, and to identifying methods of implementing the process and all of the subsequent stages of production. The discussion of these stages serves to build up a picture of the overall technological scheme of the production process. It is interesting and instructive to note that in studying other, more sophisticated, production processes, the ability of pupils to "design" various production sub-processes and equipment increases. Evidence of this may be seen in the way in which they are able to carry out production-oriented assignments in an independent, and sometimes even creative, way. For example, they are able to explain and justify a technology for producing carbonic acids through the

oxidation of paraffin (Figure 3.6) - a technology with which they were not previously familiar. Other examples include the design of a technology for synthesizing methanol out of carbon monoxide and hydrogen, a continuous (rather than discontinuous or periodic) method of obtaining sugar out of sugar beets, etc.

To conclude the present section, let us consider some of the methodological problems involved in the use of experiments and various other instruction aids in the physics course.

Raising the theoretical level of the course does not imply, as is sometimes supposed, a concomitant decrease in the role of the chemistry experiment: quite the contrary, the latter increases as one of the foundations of chemical knowledge. Without experiment, teaching becomes purely verbal: any knowledge acquired is entirely formal and insecurely grasped, and the educational function of the subject decreases markedly. As we know, the chemistry experiment has for some time now been something considerably more important than simply a means of illustrating study material. Increasingly, it is becoming a means of setting up problem-solving situations, resolving contradictions, and high-lighting the essence of objects and phenomena. At the same time, the methodological application of experimental exercises becomes more complicated, since the "gap" between directly perceived outer manifestations of chemical processes on the one hand and their deeper theoretical meaning on the other tend to increase. Hence, in order to augment the learning value of the chemistry experiment, its underlying methodology has to be oriented towards a search for new types of experiments, the development of a sound system of deductive thinking, and various forms of heuristic devices helpful in establishing links between sense perceptions and the essence of phenomena occurring in the microworld. The development of new experiments is particularly necessary when it comes to the study of theoretical issues in chemistry and production processes (the study of the properties of substances, of ways of producing them, of the interrelations that exist between properties and structure, etc;, relies in considerable measure upon experiment).

It is appropriate here to cite some examples of demonstration experiments useful in the study of chemical production processes.

Figure 3.7 shows an experiment which illustrates the thermal crackling of petroleum products. The kerosene rained down into a reactor (an iron or ceramic tube) filled with iron filings decomposes; the liquid and gaseous products of crackling ae captured; the appropriate reactions are then implemented to extract unsaturated hydrocarbons.

Figure 3.8 is a setup for demonstrating the thermal decomposition of bituminous coal. The rich long-flame (candle) coal is heated in tube A; the liquid products of dissociation are condensed in vessel B; the liquid products of dissociation are condensed in vessel B; the gaseous products are purified to remove ammonia in "irrigation tower" C; in tube D containing Fe (OH)3, the carrier is used to purify the gas in order to remove the hydrogen sulfide impurity. The gas collected in the "gas-holder" can be tested for combustibility.

Figure 3.9 shows a setup illustrating how acetaldehyde can be obtained by the hydration of acetylene. The acetylene is obtained by having calcium carbine react with water and then purifying it in a jar containing copper vitriol. The acetaldehyde is formed in a heated flask containing an aqueous solution of the mercury catalyst. It is then captured by the water contained in the test tubes further down the line, where its presence can be detected by means of familiar reactions.

Also of intrest are the setups for synthesizing hydrochloric acid (Figure 3.10) and oxidizing SO_2 up to O_3 (Figure 3.11) in the production of sulfuric acid. These figures with their detailed captions do not require special commentary.

Physics instruction in Soviet schools is continually being enriched by the introduction of new teaching aids, i.e. various kinds of tables, slides and film strips, motion-picture films and loops, novel projection equipment, etc.

The methodology implemented with these teaching aids is oriented towards their integrated use in an optimal mix within the learning process, with due regard for the particular teaching function of each aid and each device. Practice demonstrates that the pedogogical effectiveness of teaching aids depends not on their frequent and varied use, which often results in a kind of "kaleidoscopic dazzle", but rather on their rational selection and combination in conformity with the basic methodology concept underlying the presentation of this or that issue, concept, etc.

Integrated batteries of teaching aids are used in various combinations such as films together with slides or transparencies; films and tables; film clips and actual objects; one or several audio-visual aids together with chemistry experiments.

For example, a film will acquaint pupils with industrial equipment and production processes, while slides or tables present a detailed schematic breakdown of a given technology or piece of equipment. A film or loop can be used to state a problem which is then tackled by means of chemistry experiments. In other instances it is the laboratory experiment which is the starting point; after this the problem of implementing the same process in industrial conditions is discussed, whereupon tables, film clips and motion pictures are brought into play.

The sequence of inclusion of various aids in the learning process is often determined by the structural logic of the subject matter itself.

For example, in covering the production of sulfuric acid in the following sequence: end product - raw materials - chemical reactions on which the technology is based - principle stages of production - basic equipment - general underlying scientific principles of the technology, the use of teaching aids might run as follows: natural objects (the end product, raw materials) - demonstration experiments - film strip or film clips - model or schematic diagrams of industrial production lines - a motion picture film giving an overview of the entire technology.

Those who are called upon to produce the technology diagrammes and tables tend to avoid excessive detail and concentrate on the essential in a given process and/or equipment. This may be seen from the tables showing an industrial setup for producing acetylene through the decomposition of methane (Figure 3.12) and of machinery for spinning artificial acetate fibres (Figure 3.13).

One very effective device in the creation of various schematic diagrammes and tables for classroom use (as well as in illustrating textbooks) is that of comparison. For example, the outside view of an industrial setup can be compared with its schematic representation, as illustrated by the industrial production of phenolformaldehyde resin (Figure 3.14) and of the catalytic cracking process (Figure 3.15) Lessons often consist of a comparison of a demonstration experiment, a model industrial production line, and a schematic diagram of the industrial production process divested of its details. This combination is illustrated by the presentation of SO_2 conversion into SO_3.

(Figures3.16 and 3.17).

3.4. The role of the chemistry course in the education and development of pupils

Improved course content coupled with the application of active methods of instruction makes it possible to cope successfully with the problems of education and all-around personality development.

Let us see what the subject of chemistry contributes to the shaping of the pupil in a scientific world outlook in the spirit of dialectical materialism.

As early as in grade VII, pupils studying chemistry learn to use the notions of the atom and molecule to discuss the composition of substances and the nature of chemical proceses. Such knowledge, which is essential for the mastery of concepts in chemistry, also has an important philisophical side. Materialism has always dealt with the smallet known particles of matter. For this reason, the manipulation of the concepts in question convinces pupils of the existence of atoms and molecules, while at the same time shoring up the foundations of a materialistic world outlook.

The composition of various substances is taken up in the same grade. Here pupils learn that substances consist of a relatively limited number of chemical elements and that the composition of one substance has much in common with the composition of another. They then learn that substances do not exist independently of one another, but can be grouped into particular classes on the basis of similar characteristics, the classes in question being related to one another by chemical interactions. Such knowledge begins to give shape in the pupil's mind to the idea of the material unity and interrelatedness of all of the substances found in nature.

Later on, in Grade VIII, pupils see that the chemical elements constituting all conceivable substances are not isolated, but rather interrelated entities: all of them consist of the same "elementary" particles in various combinations and are subject to a common periodic law. Because of this unity of composition, elements can be transmuted. At higher levels in their education, pupils come to know about the material unity of organic and inorganic substances, their ability to undergo transformations in either direction, etc. of considerable significance in imparting this idea is information whereby the same chemical elements and the same compounds occur not only on earth, but only in the school chemistry laboratory, but also elsewhere in the Universe.

The idea of development is important to shaping a world outlook. As they go about studying chemical transformations; pupils learn to regard substances not as something immutable, but rther as entities which undergo continual transformation into new substances. Each of these substances has its past (the substance out of which it arose), a present (its structure and properties), and a future (the ability to be converted into another substance). Such an approach makes it possible to gain an understanding of the processes of change and development in nature, as well as to approach the study of phenomena dialectically. Moreover, pupils gradually come to recognize the increasingly profound essence of such transformations: they begin by identifying them with the shifting of atoms from one molecule to another, then as the rupture and formation of various types of chemical bonds, only later becoming acquainted with those elementary events of which chemical processes consist. All of this serves to lay bare the material essence of chemical transformations in greater depth and with greater power to convince.

Pupils likewise learn about the laws which govern such transformations. They know, for example, whether an oxidation-reduction reaction can occur between specific substances, whether this or that ion exchange reaction can take place in a solution, how heating can affect the rate of a reaction, how chemical equilibrium will be shifted if particular conditions change, etc. All of this knowledge generates conclusions of a philosophical character. Chemical transformations in nature occur in accordance with nature's own laws predicted on the structure and properties of substances and not upon the action of non-material, supernatural forces.

The chemistry course likewise affords a rich natural-science background for the understanding of the general law of develpment.

Pupils gradually build up their understanding of the effect of quantitative changes on changes of a qualitative nature, of the ways in which quantitative changes lead to the formation of new sustances (O_2 and O_3, SO_2 and SO_3, H_2SO_4 nitrogen oxides, homological series of organic compounds, etc.), making possible particular chemical transformations, etc.

Increasing emphasis is placed throughout the course on the dual, contradictory nature of substances and phenomena and on the unity and interdependence of opposites. As early as in Grade VII pupils learn about such opposites as the reactions of combination and decomposition, oxidation and reduction, metallic and non-metallic substances, oxidizing and reducing agents, acides and base, etc. It is these opposites which are inherent in the flow of specific chemical reactions. Pupils become aware of the fact that opposites can be combined in one and the same substance and can be manifested in particular ways, depending on conditions.

Later they learn about the dual nature of the atom, about the fact that the atom contains differently charged particles, and that as a consequence of this contradictory nature of atoms elements exhibit the properties of metals or non-metals, oxidizing or reducing properties, etc.

Chemical reactions themselves constitute unities of two opposities, involving both the joining and the separation of atoms. Chemical equilibrium is the union of two oppositely directed processes. Creating a particular set of conditions, we require that a reaction proceed in the desired direction.

The study of chemistry gives students a grasp of a number of other important philosophical ideas. Some of thee are as follows.

As early as in grade VII pupils recognize that the properties of a molecule are not the sum of the properties of its constituent atoms, and that a molecule is a qualitively new entity. At more advanced levels, and especially in studying organic chemistry, they learn about the interaction of atoms within the molecule, about the fact that this is an entirely material phenomenon resulting from the interaction of the electron structures of atoms and from the distribution and shifting of electron densities of chemical bonds. They thus gain an intuitive grasp of the whole and its parts: the whole is not the sum of its parts, but rather the resultant of the interrelation and interaction of those parts.

The discussion of homological series within the organic chemistry course sheds light on the interrelationship of the general, the particular and unique as one of the forms in which the multifaceted nature of substances is revealed: The class of compounds under consideration constitutes the general; a homological series within that class is the particular characterized by certain salient features, while a representative of that series is something unique manifesting a specific set of attributes.

A school subject structured according to the principle of concept development sets out before pupils a process of learning whereby one proceeds from a given phenomenon to its increasingly deeper essence by way of contriductions and their subsequent resolution. The study of increasingly deeper theories, their continual verification, and the confirmation and of their implications convince the pupil of the objective character of scientific theories and of the possibility of understanding the world around us.

Until grade X all problems of a philosophical character are dealt with in languages understandable to the pupil, without recourse to philosophical terminology. However, after the elements of dialectical materialism and the theory of knowledge have been covered in the social studies course in grade X, appropriate issues in chemistry are taken up in the light of philosophical notions already familiar to the pupil.

The principal philosophical concepts and ideas which have to be grasped by pupils in a given grade are set out in the section of the curriculum entitled "Knowledge and skills requirements". In the case of the organic chemistry course, for example, these are as follows:

Understanding of the reasons behind the multiplicity of organic substances; of the material unity and interrelationship of organic and inorganic substances; of the unique, particular and general in the consideration of homological series and classes of organic compounds; of the cause-and-effect relationships between the composition, structure and properties of substances; the development of knowledge by proceeding from phenomena to their increasingly profound essence. The ability to illustrate the following concepts by means of examples: essence and phenomenon; possibility and reality; the internal contradictory nature of objects as a driving force in their development; the transformation of quantitive changes into qualitative changes; the understandability of phenomena.

The usefulness of the chemistry course in inculcating philosophical notions is augmented by a panoply of methodological devices. The most important of these include the analysis by the teacher of the facts and concepts studied; the generalization of knowledge at various levels and the assessment of that knowledge from a philosophical standpoint; the establishment of intersubject links; the implementation of problem-oriented approach to learning to stimulate independent learning activity by pupils, etc.

The cardinal feature of the above methodological approaches is their high degree of generality. This is one of the reasons why review and generalizing units form an integral part of the curriculum (see the list of topics covered in the chemistry course at the beginning of this chapter). Such generalizing units are associated with the study of principal theories and with the completion of certain major subject matter areas. The earliest generalizations are presented at the level of the chemical form of notion of matter, i.e., facts are generalized into the concepts, laws and theories of chemistry. The next level of generalization is that of science in general, when philosophical ideas are shaped on the basis of actual material and notions drawn from a variety of scientific disciplines. As noted earlier, the highest level of philosophical generality is achieved in grade X on the basis of interrelations with concepts generated in the humanities.

All of the work done by the teacher in presenting and analyzing new knowledge and in highlighting its philosophical significance entails a contribution on the part of pupils themselves. In specific terms, youngsters are asked to solve various types of learning problems, to establish intersubject links significant in a philosophical sense, and to apply philosophical insights to the assessment of new objects, etc.

The implementation of the polytechnical principal in chemistry instruction opens up extensive opportunities for bringing up youngters in a spirit of commitment to Communism.

The presentation of industrial processes and the principal areas in which the national economy depends on chemistry and chemicals enables the chemistry teacher to conduct the systematic and ideological and political indoctrination of pupils. By analogy with the shaping of a scientific-materialistic world outlook by means of courses structured according to the principle of concept development, ideological-political indoctrination relies upon the treatment of chemical industries as industries developing within the context of a socialist society. This enables the teacher to acquaint pupils with the achievements of the national industries over the years of Soviet power while highlighting the tasks of future industrial development and further progress in science and technology. Familiarization with the achievements and prospects of the development of chemistry in the USSR is a good opportunity to show pupils how much attention V.I. Lenin gave to the establishment and development of the Soviet chemical industry and how his precepts have been and are being implimented by the Soviet people, as well as to explain the most important decisions of the Communist Party and Soviet Government concerning the development of the chemical industry and the chemization of the national economy, with due emphasis on decisions adopted by various Party Congresses.

Pupils are greatly impressed by their new-found ability to understand the scientific content and significance of such decisions on the basis of knowledge acquired in the classroom. They come to understand, for example, why Party decisions and national economic plans now place so much emphasis on steel production by means of oxygen converters and electric furnaces. It is satisfying to understand the principle behind the technology of obtaining iron from iron ore bypassing the blast-furnace process, why it is that such importance is being given to the production of high-octane benzenes and aromatic hydrocarbons, why liquid paraffins are needed for the mirco-biological industry, precisely what types of rubber are meant when "total substitutes for natural rubber" are mentioned, etc. Discussions of chemical industries offer scope for dealing with such general trends in science and technology as the supplanting of periodic processes by processes which are continuous, multistage processes by processes involved only a few stages, the construction of aggregates of large unit capacity, the maximum use of chemical reaction energy, the integrated use of raw materials, the creation of waste-free industries, etc.

All of this enables pupils to gain an understanding of the scientific thinking underlying Party policy in the development of the national economy and to appreciate the significance of decisions taken to ensure the success of Communist construction and the improvement of living standards in the USSR; The study of chemistry is therefore a means of raising the Communist conscientiousness of secondary school pupils and their level of ideological preparedness.

The scientifically-enriched chemistry course structured according to the principle of concept development and characterized by the increased use of active teaching and learning methods is a major encouragement to the mental development of pupils. Full reliance upon the generalizing, explaining, and predicting potential of each theory studied requires the extensive use of inductive and deductive reasoning, analysis and synthesis, advancement of hypotheses, searching for proofs, identification of cause-and-effect relationships, etc. All of this implies intensive thinking and therefore encourages the development of the intellect and the ability of the pupil to acquire still more knowledge.

In order to be mastered successfully, individual course units require the utilization of specific mental operations. Thus, in studying the basic concepts of chemistry, the pupil is called upon to compare substances and processes and to isolate the salient features of concepts, i.e., to analyze and synthesize; the study of the periodic law requires considerable generalizing and abstracting ability; the study of elements according to groups within the periodic table encourages the development of deductive reasoning and the ability to advance and verify hypotheses, etc. All of these mental operations are brought to bear at the "interface" between facts and theoretical knowledge (on the way from facts to theory and vice versa). For this

reason, incidentally, the more appropriate the balance struck between theory and factual material within a given subject, the greater the opportunity for seeing the principle of developmentally useful training realized.

The structuring of the course in accordance with the principle of going deeper and deeper into the subject matter is so effective in encouraging the development of pupils for the simple reason that as they proceed from one level to the next, mastering each new scientific idea, law and theory, they, at the same time, gain mastery of a new system of mental operations involving material drawn from chemistry, i.e., of a higher level of thinking, thus advancing their intellectual development. The description of a chemical element by a pupil in the early stages of the chemistry course involves one system of judgements; it is an entirely different level of reasoning which is manifested when that same pupil derives the properties of an element from its position in the periodic table and from the structure of its atom. The same may be said of the interpretation of any chemical concept.

The basic skills requirements characterizing the level of pupil development are set out in the chemistry course curriculum.

For example, grade IX pupils must be able "to draw deductive conclusions, to advance hypotheses, to adduce scientific justifications of such hypotheses, to carry out mental and real experiments, and to draw conclusions and make generalizations".

Pupils in grade X are called upon to be able to "employ comparison, analysis and synthesis, as well as to systematize and generalize on the basis of organic chemistry material, as well as to formulate propositions concerning the properties of substances on the basis of their structure, and concerning the structure of substances on the basis of their properties".

The level of development achieved by pupils may be assessed on the basis of various skills, such as the ability to relate the outer signs of a phenomenon to its essential nature and the properties of a substance to its structure; to employ analytical and synthetic reasoning in dealing with the facts of chemistry; to draw conclusions inductively and deductively; to apply theoretical knowledge in explaining and predicting the facts of chemistry; to solve learning problems; to manifest basic creative skills.

But as is the case with achieving purely developmental gaols, the attainment of these objectives requires purposeful action and activity on the part of the teacher. The development of the pupil is stimulated by all learning methods which act to mobilize thinking: the problem-oriented structuring of lessons, heuristic discussions, varius forms of independent activity, problem solving, the execution of increasingly more complicated assignments, etc

A pupil can learn to perform the required mental operations successfully only if the teacher takes care to teach him to perform such operations in good time. Thus, such mental operations important in chemistry as comparison, abstraction and generalization are already taught in grades VII and VIII. As his skill in applying these operations improves, the pupil gradually makes the transition from the executant level to the performance of operations by analogy and to the application of the appropriate mental operations to new situations.

At the same time, pupils are given a chance to develop the skills necessary for learning chemistry and for developing their minds as they go about learning it. These include the ability to apply knowledge, to solve problems, to carry out and explain chemistry experiments, to use reference literature, etc.

An important role within the overall system of methodological aids directed at developing reasoning ability is that of assignments structured by an increasing level of difficulty. A succession of such assignments can be undertaken by a single pupil as he continues to progress; they can also be used in a differentiated manner i.. dealing with students with differing levels of ability and achievement.

Here is a sample sequence of increasingly complicated calculation problems for pupils in grade VII.

" 1. How much sulfur is required to react with 28 g of iron in obtaining iron sulfide FeS?

2. How much sulfur and how much iron are required to obtain 88 g of iron sulfide?

3. Devise a problem of obtaining copper sulfide CuS in such a way that 2 g of copper residue are left after the reaction has gone to completion."

The solution of the first problem on the basis of relative atomic masses requires just one mathematical operation; the second problem is more complicated because of the fact that the calculations have to be carried out for two elements; the third problem is the most complicated one of the three, requiring allowance for an additional factor, as well as calling for the independent formulation of the condition of the problem.

The following set of problem illustrates the way in which the level of difficulty is increased in a drawing assignment.

"1. Make drawings of a gas meter and a Kipp generator. Indicate the purpose of each device and of its parts in your captions.

2. Make drawings of the following: a) An experiment in which iron is burned in oxygen; b) An experiment involving the decomposition of malachite. Indicate the conditions under which these reactions take place and indicate the signs of each reaction.

3. Two setups have been devised for obtaining hydrogen and oxygen gas. Each setup consists of two test tubes, a plug, and a gas offtake pipe. How will one setup differ from the other? Give your answer in the form of drawings with explanatory captions."

Problem sets consisting of problems of increasing difficulty are used throughout the chemistry course. For example, the study of the theory of electrolytic dissociation in grade IX includes a problem set involving an increasingly difficult sequence of mental operations:

"1. Which are the ions formed upon the dissociation of the following compounds: barium hydroxide, phosphoric acid, aluminium nitrate? Write out the dissociation equations.

2. Indicate which ions are formed when the following are diluted in water: a) acides; b) bases; c) salts.

3. What kinds of substances react with: a) copper sulphate; b) zinc chloride? Write out the appropriate chemical equations."

In the first problem, all that is needed to indicate the ions is a knowledge of the formulae for the corresponding compounds; the second problem requires expressing the dissociation of substances belonging to various classes in general form, which is more difficult; the third problem requires the pupil not only to know which ions are formed upon dissociation, but also the chemical properties of the substances involved and the conditions under which the reactions occur.

The system of assignments made up of problems of increasing difficulty is particularly effective in the organic chemistry course in grade X, and especially with reference to the structure of substances. Once the teacher has described the ways of establishing structure as exemplified by some simple hydrocarbons, pupils are asked to establish in a similar way the characteristic structure of other classes of compounds by carrying out assignments involving an increasing degree of independent thinking. One reliable indicator of the level of knowledge and maturity achieved by pupils is the fact that many youngsters are able to use previously acquired knowledge to establish the basic structural elements of monosaccharide (the aldehyde form of glucose). Basing themselves on the molecular formula of the substance, they suggest that the molecule of this compound includes a considerable number of oxygen-containing functional groups. Already familiar with the properties of the corresponding compounds, they establish experimentally that the given substance is a multi-atomic alcohol and aldehyde. Additional information to the effect that the molecule contains five hydroxyl groups provides them with a basis for arriving at the structural formula.

The present chapter has been concerned with some of the aspects of the general chemistry course for Soviet schools and the methods involved in its presentation. Streamlining and improvement of the chemistry course will certainly continue in step with the advance of science, material production, and the increasing requirements imposed by a developing socialist society in regard to its secondary schools. Without drawing on the various issues involved in future development of the chemistry course, let us merely note what is at issue at the present time.

Of the two principal systems of chemical knowledge, namely the theory of the structure of substances and the theory of chemical processes, the former is reflected much more fully in the curriculum. In view of the fact that chemical processes are receiving increasing attention in chemistry research, attempts are being made to shift this balance in favour of the latter aspect.

Something similar will probably have to be done in regard to polytechnically-oriented information. Until now, the main area of emphasis has been industrial chemical processes. But what is becoming central today is the creation of new materials with a variety of properties specified in advance. This calls for greater emphasis on the materials-science aspects of polytechnical education, i.e;, on familiarization with the composition, structure and properties of materials used in modern technology, together with the scientific principles of their production and use.

Studies indicate that there are opportunities for the more general investigation of groups of chemical elements and classes of organic compounds. This should render the knowledge newly acquired by pupils more effective, making additional time available for dealing with any number of other learning tasks.

The knowledge concerning inorganic and organic chemistry built up by pupils during the four-year chemistry course requires greater generalization in its final stages than is the case at present. But the end of the course, such knowledge should be brought up to a uniformly high level; due emphasis having been placed on general principles, laws and theories. This is important for the correct understanding of the chemical form of motion of matter, of the place of chemistry in the shaping of a unified scientific world picture, and of the role of science in the creation of the material and technological basis of Communism.

3.5. ANNEX III

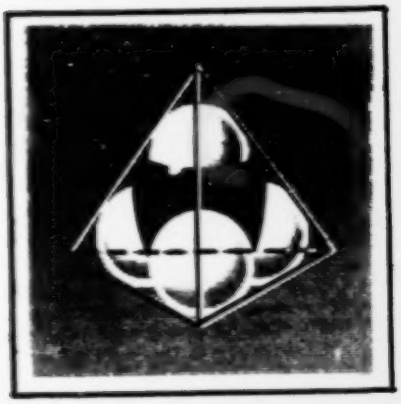


Figure 3.1. Model of the methane molecule

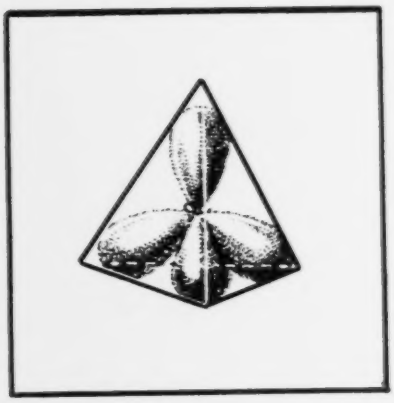


Figure 3.2. Hybrid electron clouds of the carbon atom.

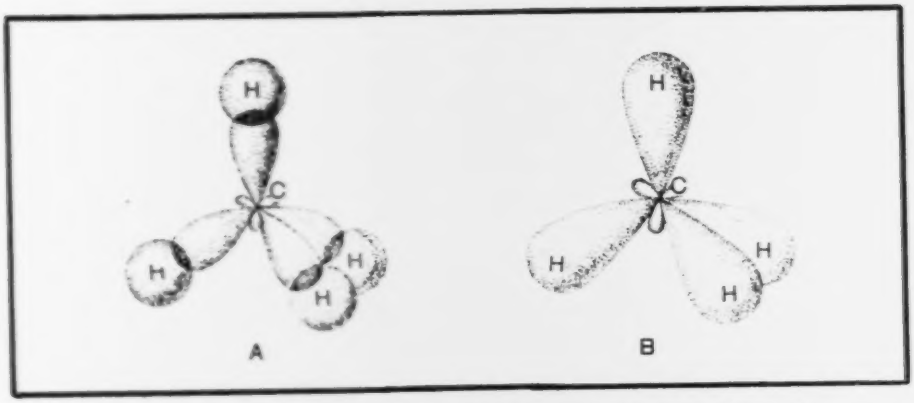


Figure 3.3. Covalent chemical bonds in the methane molecule: A) overlapping of the electron clouds of carbon atoms with hydrogen atoms; B) formation of common electron clouds of C-H bonds

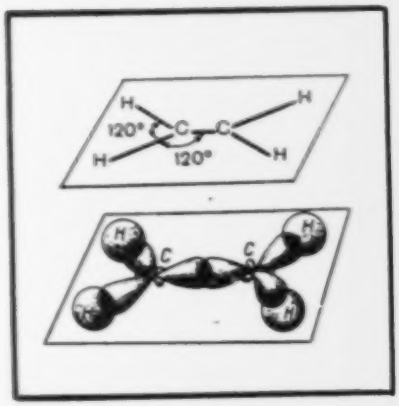


Figure 3.4. Schematic diagram of sigma-bond formation in an ethylene molecule.

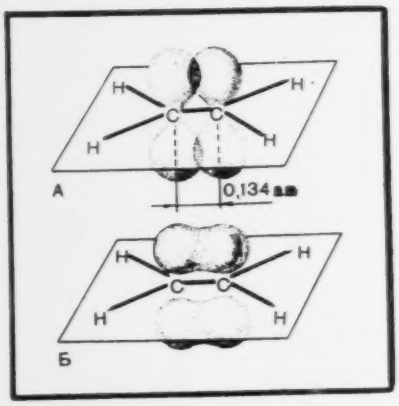


Figure 3.5. Schematic diagram of pi-bond formation in an ethylene molecule: A) Lateral overlapping of p-electron clouds; B) distribution of common pi-bond cloud above and below the plane of atomic nuclei

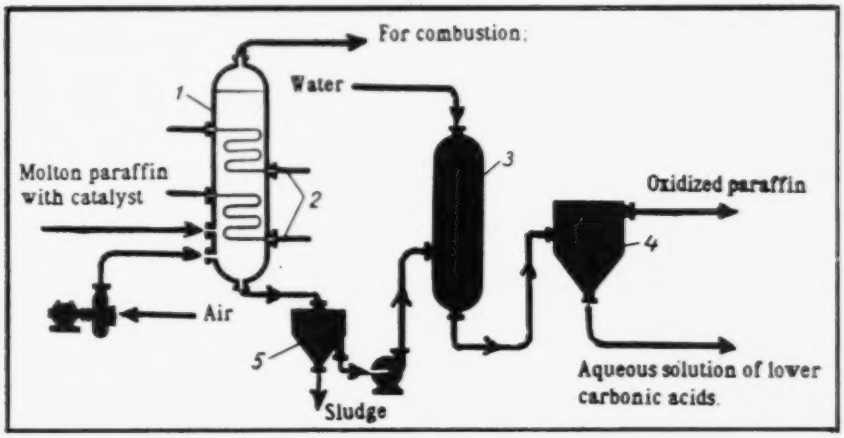


Figure 3.6. Diagram of industrial process for obtaining carbonic acids by paraffin oxidation: 1) oxidation column; 2) coil pipes; 3) rinsing column. 4) separator 5)settling tank.

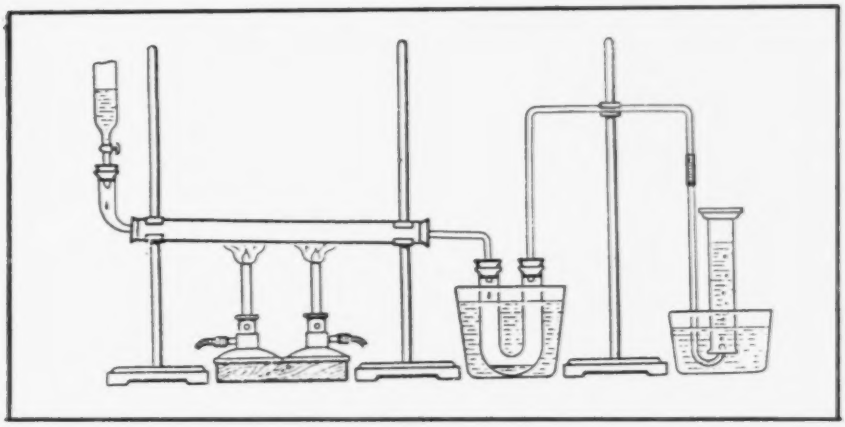


Figure 3.7. Kerosene cracking in tube furnace

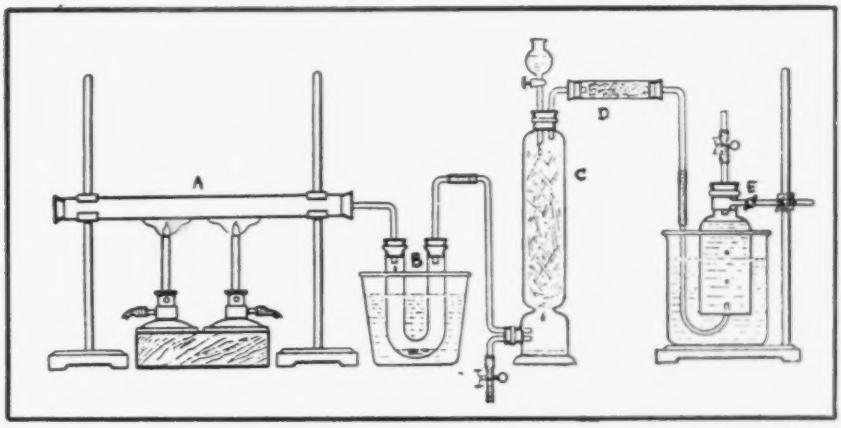


Figure 3.8. Decomposition of bituminous coal upon heating

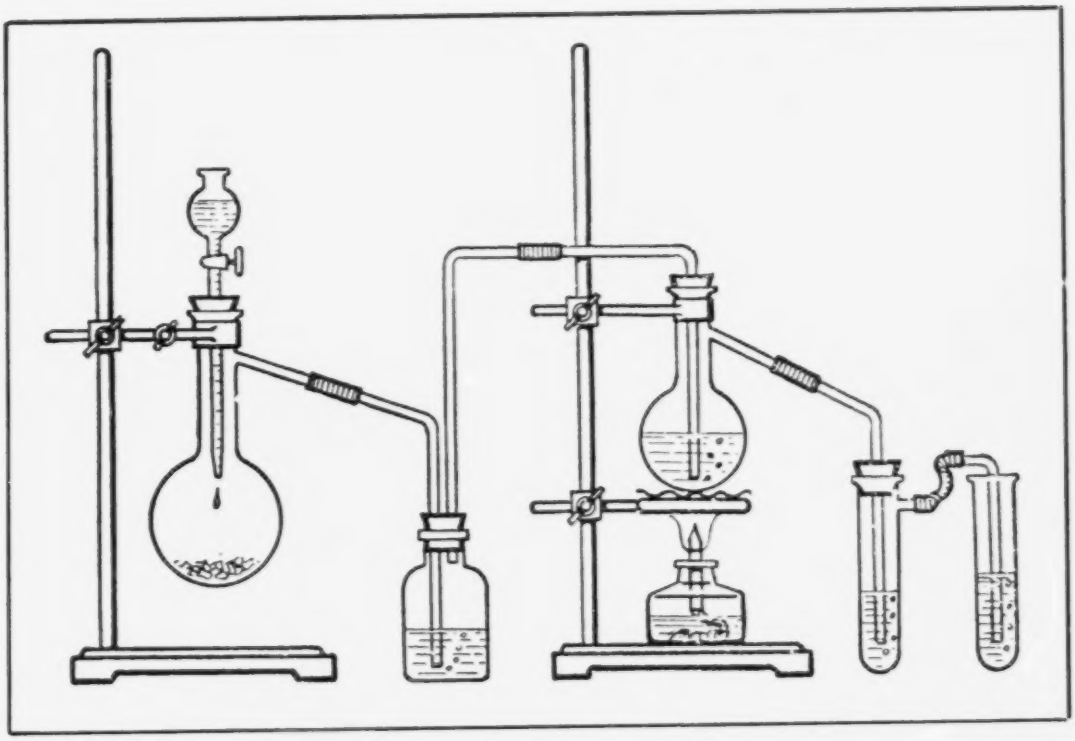


Figure 3.9. Obtaining acetaldehyde by acetylene hydration

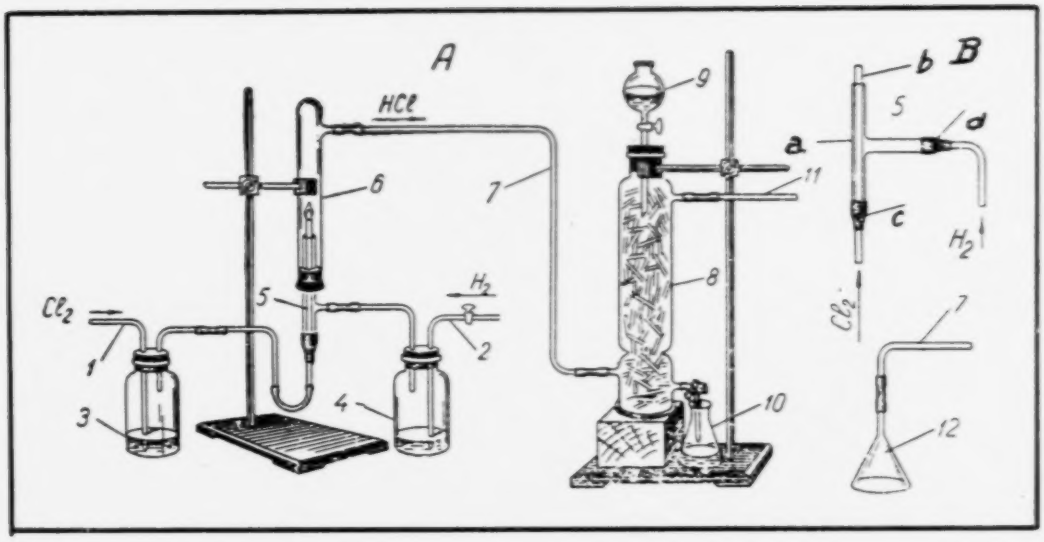


Figure 3.10. Setup for synthesizing hydrochloric acid. A. Overall view: 1. chlorine inlet tube; 2. hydrogen inlet tube; 3. and 4. rinsing jars containing concentrated sulfuric acid; 5. burner for hydrogen combustion in chlorine; 6. hydrogen chloride collection vessel; 7. hydrogen chloride outlet tube; 8. crushed-glass absorption column; 9. water-filled drop funnel; 10. flask for collecting the resulting hydfochloric acid; 11. gas outlet tube leading to aspirator (or water-jet pump). B. Parts of setup: 5. burner for hydrogen combustion in chlorine: a - T-joint; b - small-bore glass tube; c and d - rubber tubing; 12 - glass funnel (instead of hydrogen chloride collection vessel 6) with gas outlet tube 7.

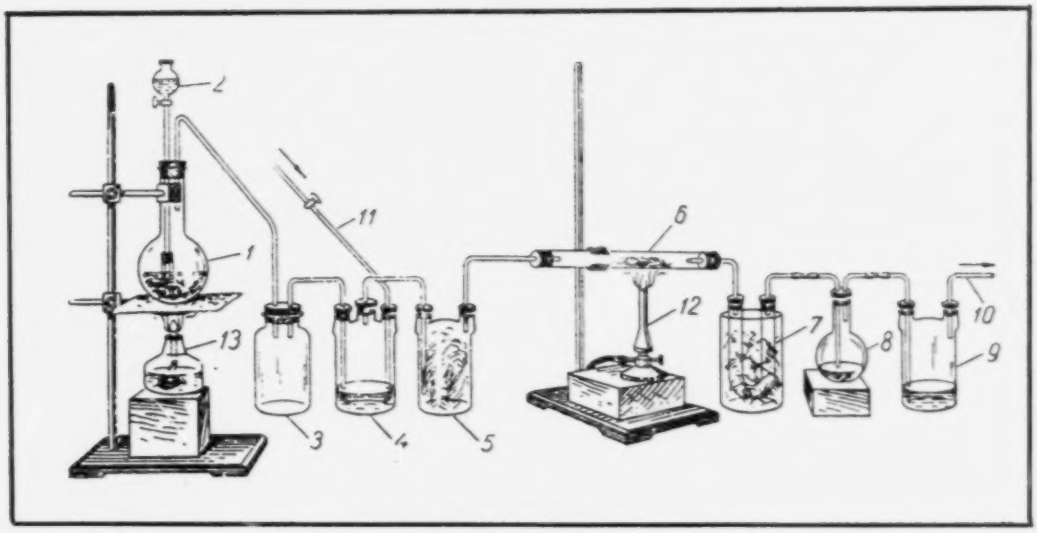


Figure 3.11. Setup for the catalytic oxidation of sulfur dioxide to sulfuric anhydride: 1. Flask filled with copper fillings (or sodium bisulfite); 2. dropping funnel containing concentrated sulfuric acid; 3. safety jar; 4. three-necked jar containing concentrated sulfuric acid; 5. two-necked jar containing glass wool; 6. tube made of high-melting glass (porcelain or grog) containing catalyst; 7. U-shaped tube immersed in coolant; 8. flask containing water; 9. two-necked jar containing concentrated sulfuric acid; 10. gas outlet to aspirator; 11. tube leading gas meter with oxygen; 12. gas burner; 13. alcohol lamp.

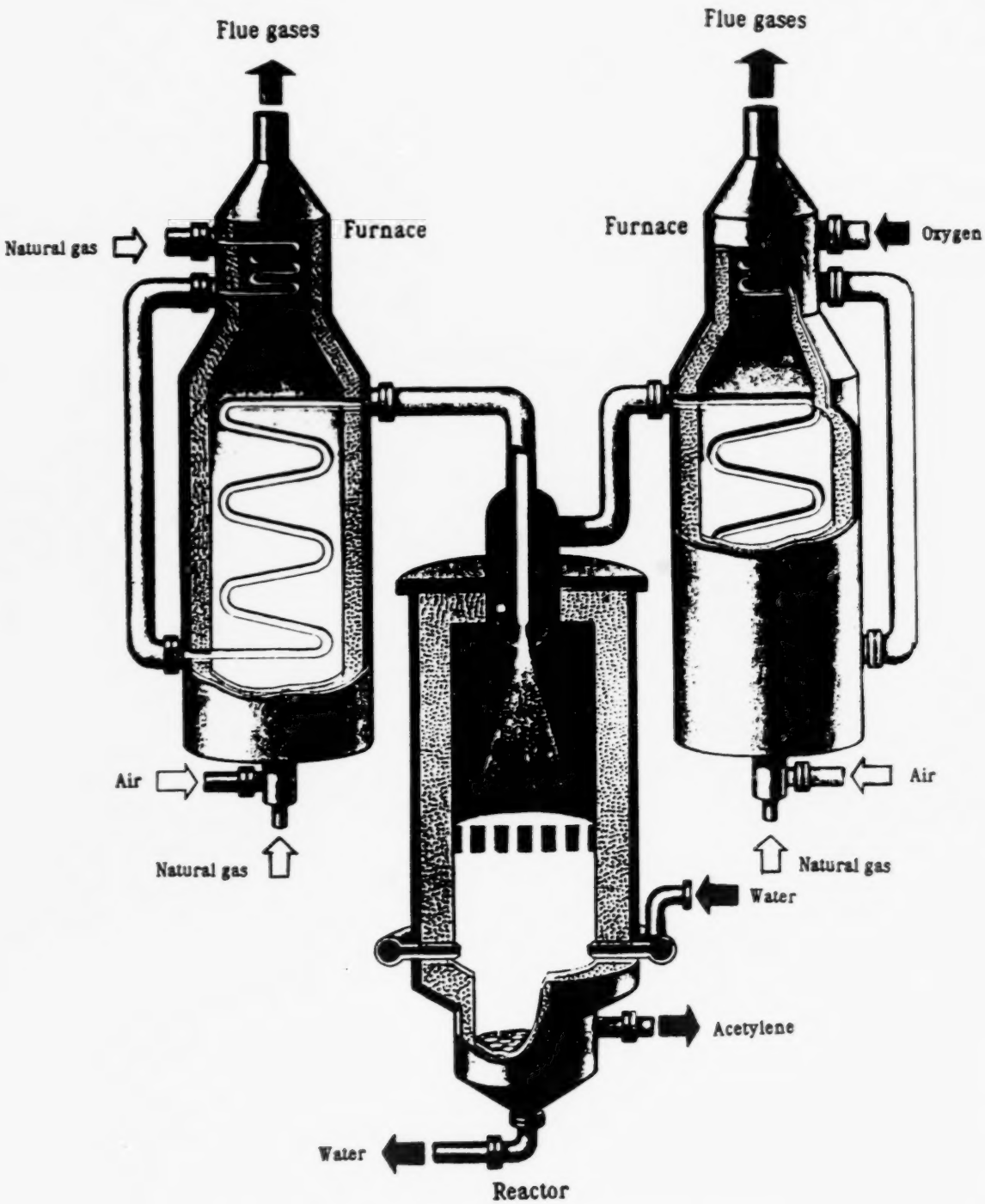
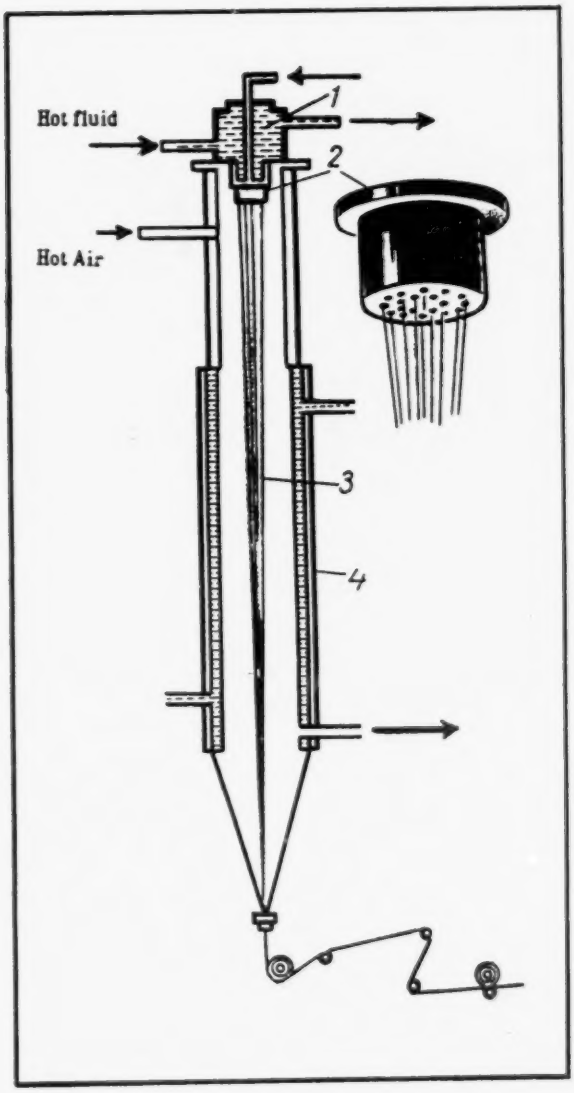


Figure 3.12. Industrial setup for obtaining acetylene from methane

Figure 3.13. Diagram of device for acetate fibre production.
1. Spinning head; 2. nozzle; 3. yarn; 4. shaft



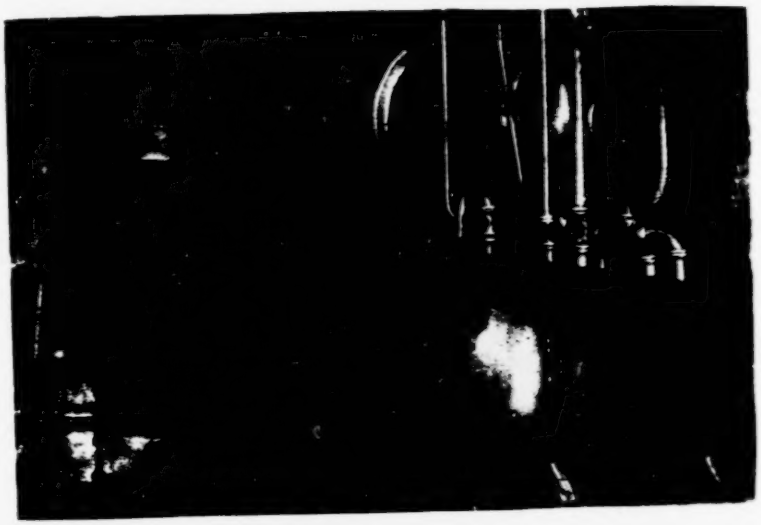
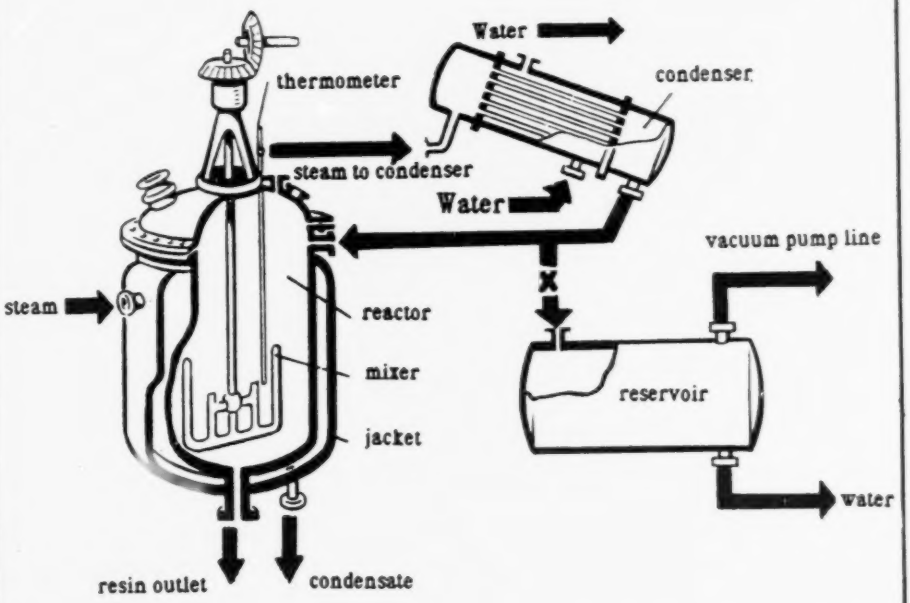


Figure 3.14. Industrial setup for producing phenol formaldehyde resin



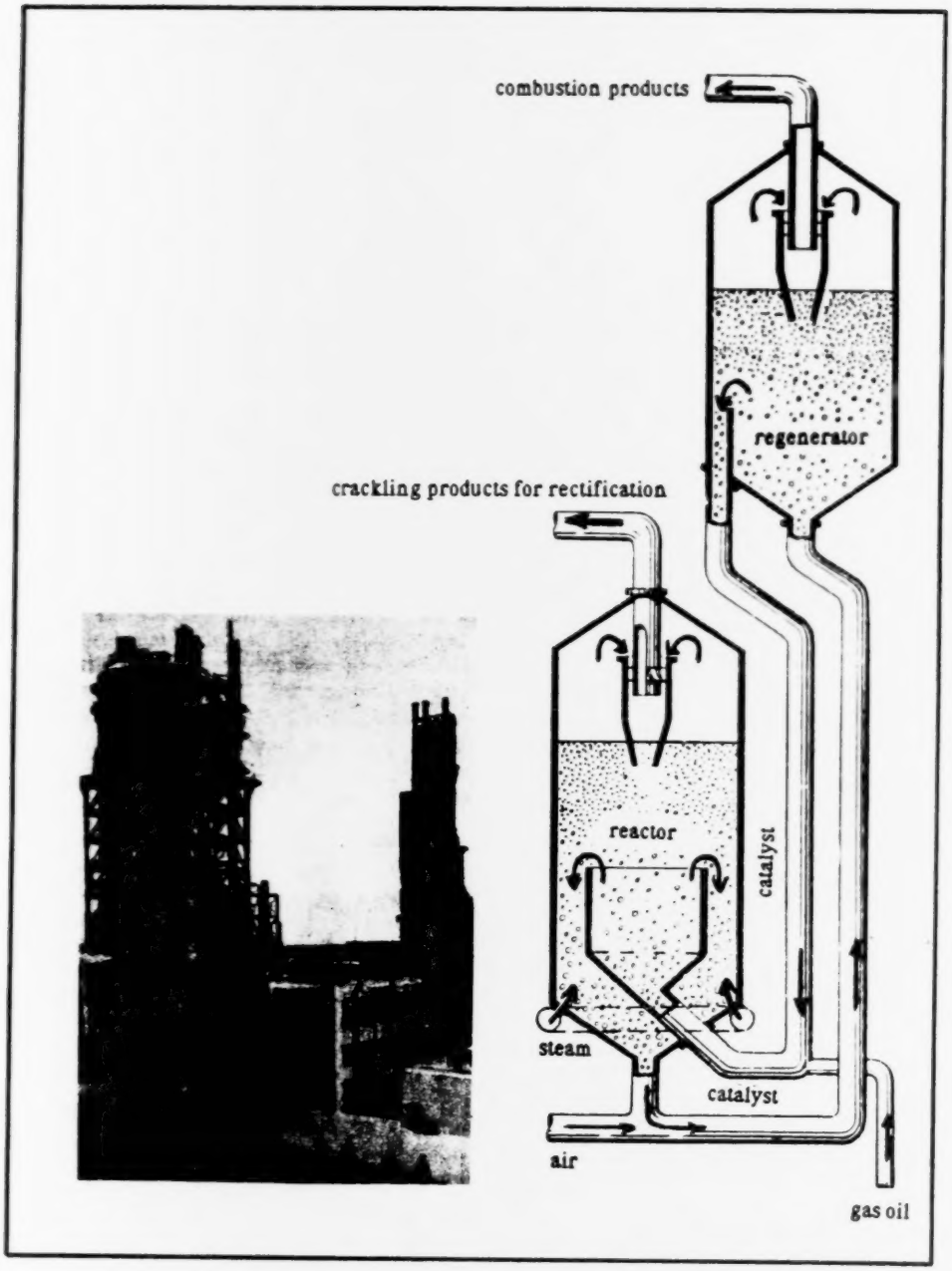


Figure 3.15. Industrial setup for catalytic cracking in a 'boiling layer'

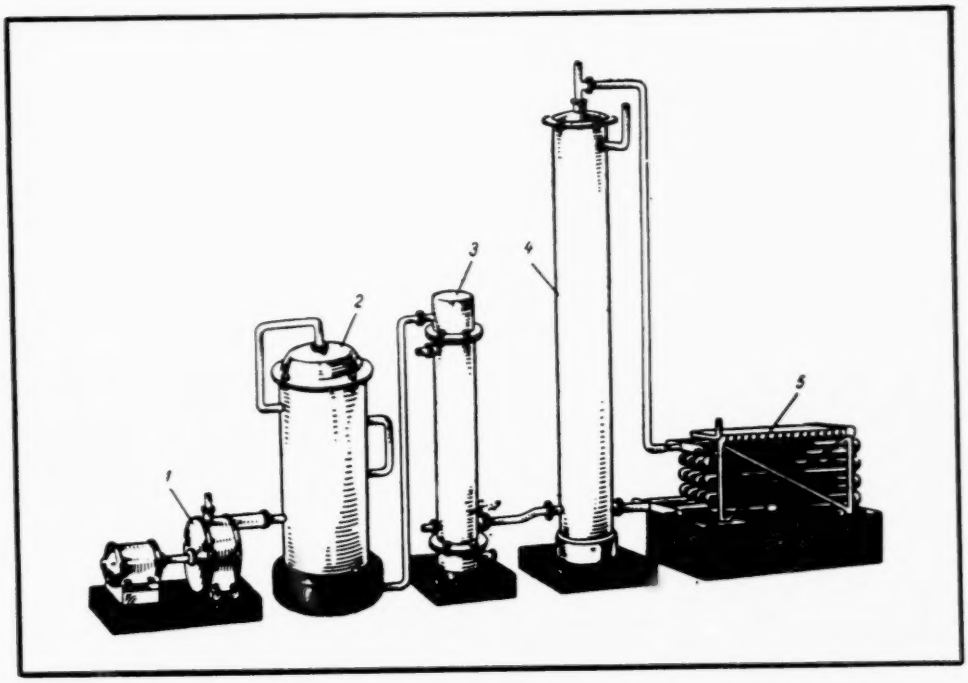


Figure 3.16. Model of setup for supfur dioxide oxidation and sulfur anhydride absorption: 1. compression for delivering gas to the contact apparatus; 2. contact apparatus; 3. refrigerator; 4. absorption column; 5. refrigerator for cooling the circulating liquid (pump not shown in diagram of setup).

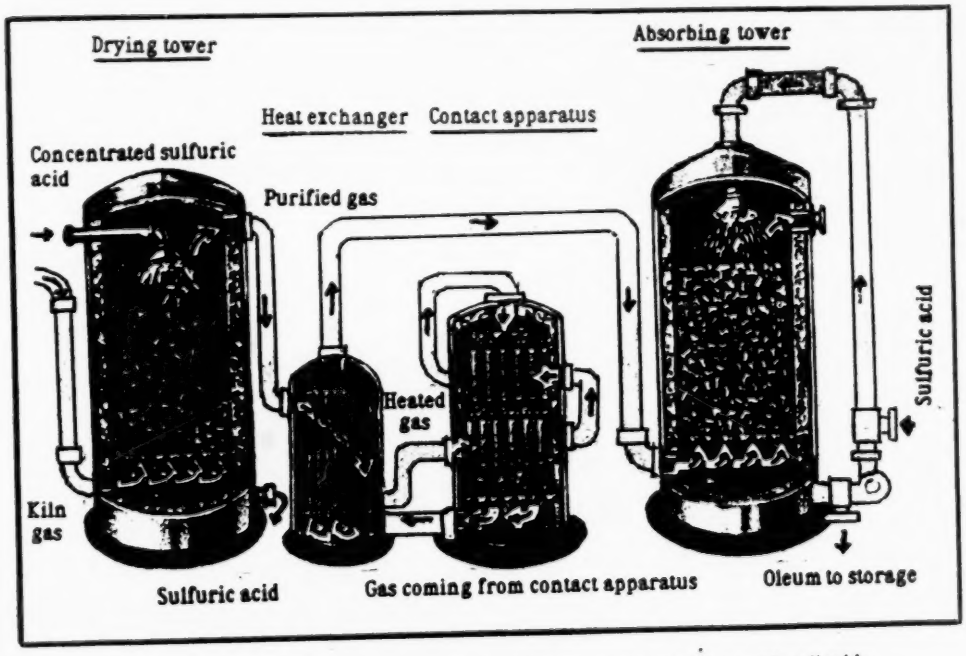


Figure 3.17. Schematic diagram of industrial setup for oxidizing sulfur dioxide.

ANNOTATED BIBLIOGRAPHY

CHEMISTRY
Literature for the teacher

1. Tsvetkov, L.A., Ivanova, R.G., Polosin, V.S. et al. Obshchaya metodika obucheniya khimii. Soderzhanie i metody obucheniya: Posobie dlya uchitelei (The General Methodology of Chemistry Teaching. Content and Methods of Instruction: An Aid for Teachers). Moscow, Prosveshchenie, 1981.

This guide takes up the basic methodological problems facing the chemistry teacher. The objectives and contents of school chemistry are described and the structure of the subject justified. There is a detailed discussion of teaching methods, a description of the didactic advantages of particular methods, a classification of such methods, and a discussion of the principles which should guide the selection and combination of such methods in the study of various topics. There is also a discussion of the organizational forms which chemistry introduction might take, types of lessons, lesson structure, and requirements as to the structuring of exercises. The problem of inter-subject links in the teaching of chemistry is considered. The didactic functions of the teaching of chemistry is considered. The didactic functions of the chemistry experiment and the technical resources for chemistry teaching, as well as appropriate ways of using such resources, all receive thorough treatment. The authors then go on to describe various forms of chemistry-related out-of-class activities and the teacher's role as occupational adviser both in and out of the classroom. The guide was prepared on the basis of theoretical and experimental findings concerning the contents of chemistry courses and methods of teaching chemistry, school experience, and a general survey of Soviet achievements in the field of chemistry education and training.

2. Smirnova, T.V., Zueva, M.V., Savich, T.Z. et all., Obschchaya metodika obucheniya khimii. Uchebno-vospitatel'nye voprosy: Posobie dlya uchitelei (The General Methodology of Chemistry Teaching. Problems of Learning and Upbringing: An Aid for Teachers). Moscow, Prosveshchenie 1982.

This guide is a complement to the above General Methodology. The basic problems of education and upbringing through the teaching of chemistry are dealt with from the standpoint of methodology. These include the following issues: the upbringing of young people in the spirit of Communism; pupil development through the study of chemistry; the shaping of systems of concepts concerning the structure of matter and chemical reactions; the shaping of basic concepts in organic chemistry; the methodology of instruction concerning the fundamentals of the chemistry industry; the shaping of practical laboratory skills and abilities in pupils, knowledge assessment methods; concepts and methodologies for optional work in chemistry.

3. Khodakov, Yu. V., Epshtein, D.A., Gloriozov, P.A. et al.
Prepodavanie neorganicheski khimii v 7-8 klassakh: Posobie dlya uchitelei (The Teaching of Inorganic Chemistry in Grades VII and VIII: An Aid for Teachers). Moscow, Prosveshchenie, 1980. (Third edition, revised).

The introductory part of this guide deals with the purpose of studying inorganic chemistry and with certain general methodological approaches applicable to the entire secondary-school course. There follows a detailed presentation of the methodology of teaching all topics prescribed by the curriculum. The relevant ideas are discussed not on a lesson-by-lesson basis, but rather according to the system of concepts and issues to be mastered by the pupil. For example, the chapter entitled "The basic concepts of chemistry" deals with the gradual assimilation by the pupil of notions concerning the composition of substances, pure substances and mixtures, physical and chemical phenomena, atoms and relative atomic mass; it then goes on to discuss the presentation of chemical elements, chemical formulae, relative molecular mass, the law of conservation of mass, chemical equations, etc.

4. Khodakov, Yu.V., Epshtein, D.A., Gloriozov, P.A. et al., Prepodavanie neorganicheskoi khimii v 9 klasse: Posobie dlya uchitelei (The Teaching of Inorganic Chemistry in Grade IX: An Aid for Teachers). Moscow, Prsveshchenie, 1980. (Third edition, revised).

This guide is similar to the previous entry in its orientation and structure, and constitutes its logical extension. It begins with a chapter setting out the aims of chemistry teaching and learning in grade IX, and then describes the methodology of dealing with all units and topics prescribed by the curriculum. Explanations are given concerning the content and structure of topics. This is followed by a discussion of the choice of methods and methodological devices with special emphasis on items of knowledge to be stressed. Hints as to how to avoid common pupil errors are given; along with advice about testing knowledge and skills. Much attention is devoted to methods of presenting information about the chemical industries and the use of chemicals in the national economy.

5. Tsvetkov, L.A., Prepodavanie organicheskoi khimii v 10 klasse: Posobire dlya uchitelei (The Teaching of Organic Chemistry in Grade X: An Aid for Teacher). Moscow, Prosveshchenie, 1973. (Second edition, revised).

The first part of the guide is of a general nature, setting out the scientific-pedagogical foundations of the secondary school course in organic chemistry and analyzing the contents of the coresponding curriculum. Among the methodological issues discussed are the development of pupil thinking, the problem-solving approach to instruction, forms of independent work by pupils, the methodological devices for the presentation and development of major concepts. The second part deals with the methodology to be followed in presenting various specific course topics. There are suggestions concerning the planning of studies, sample lesson plans, and comments on the choice of teaching methods and devices. The role of organic chemistry studies in promoting intellectual development and in the shaping of a scientific-materialistic world outlook is discussed.

6. Ivanova, R.G. and Cherkasova, A.M., Izuchenie khimii v 7 - 8 klassakh: Posobie dlya uchitelei (The Study of Chemistry in Grades VII and VIII: An Aid for Teachers). Moscow, Prosveshchenie, 1982. (Second edition, with additional material).

This guide is a compendium of so-called "methodological commentaries" on lessons covering all topics of the chemistry course in grades VII and VIII. The first part sets out general approaches to lessons and the requirements to be met. Suggestions on the structuring and planning of lessons are included. Subsequent sections deal with the ways in which general recommendations can be implemented in presenting specific lessons. Several different versions of lessons on the same topic are offered, accompanied by graded assignments for independent work by pupils as well as test and quiz material.

7. Ivanova, R.G., Izuchenie khimii v 9 klasse: j Posobie dlya uchitelei (The Study of Chemistry in Grade IX: An Aid for Teachers). Moscow, Prosveshchenie, 1979.

This guide describes the methodology of conducting chemistry lessons on all topics to be covered in grade IX. Suggestions about varying lesson structure are given, along with recommendations for enhancing keeness to learn on the part of the pupil. Methodologies involved in performing various chemistry experiments and in using technical resources for learning and instruction are discussed. Much attention is devoted to the development of thinking ability and the shaping of a scientific-materialistic world outlook.

8. Osokina, G.N., Izuchenie khimii v 10 klasse: Posobie dlya uchitelei (The Study of Chemistry in grade X: An Aid for Teachers). Moscow, Prosveshchenie, 1980.

The present guide is structured along the same lines as the two preceding volumes. It contains an extended methodological commentary of each lesson in organic chemistry, including the final series of lessons summarizing knowledge in both inorganic and organic chemistry already mastered by the pupil. A variety of lesson structures and methods is proposed, with particular emphasis on independent learning and creativity on the part of the pupil. The shaping of the appropriate world outlook is also stressed. The ideas and principles of learning with an emphasis on problem solving are discussed. The guide reflects the author's extensive personal exprience as a teacher.

9. Chertkov; I.N., Metdika formirovaniya u uchashchikhsya osnovnykn ponyatii khimii: Posobie dlya uchitelei (A Methodology for Conveying the Basic Concepts of Chemistry to Pupils: An Aid for Teachers). Moscow, Prosveshchenie, 1979.

This methodological guide is neither thematic nor lesson-based in its structure. Rather , it is concerned with the basic concepts of organic chemistry, tracing their development throughout the chemistry course. It classifies the relevant concepts, fits them into a logical general system, and specifies conditions for their successful mastery and increasingly profound understanding by the pupil. The stress is on the concepts of classical structural theory, stereochemistry, the theory of the electron structure of organic compounds, the interaction of atoms in molecules, and the mechanisms and patterns (regularities) of chemical rections. The contents are based on the author's many years of experimental work.

10. Zueva, M.V., Razvitie uchashchikhsya pri obuchenii khimii: Posobie dlya uchitelei (The Development of Pupils Through the Study of Chemistry: An Aid for Teachers). Moscow, Prosveshchenie, 1978.

Unlike previous guides, the present publication addresses a single methodological issue, namely that of pupils' development through the study of the subject in question. A description is given of the didactic principles of instruction to stimulate development and of the ways in which these principles can be used in giving the chemistry course. Considerable attention is devoted to helping pupils to master the mental operations (comparison, abstraction, generalization) necessary for the successful learning of chemistry, as well as to become skilled in applying their knowledge. The issues dealt with from the standpoint of pupils' development include training in problem-solving techniques, the carrrying out of chemistry experiments, and the need for a differentiated approach to pupils studying chemistry (i.e. for an approach which makes allowances for individual differences). The contents of the book are based on the author's many years of research in this special field.

Literature for the pupil

1. Khodakov; Yu.V;, Epshtein, D.A. and Gloriozov, P.A., Neorganicheskaya khimiya, uchebnik dlya 7_8 klassov ((Inorganic chemistry, A Textbook for Grades VII and VIII). Moscow, Prosveshchenie, 1981. (Thirteenth edition, revised).

This textbook was written with curriculum requirements in mind. It is noteworthy of its simplicity and lucidity of presentation and its reliance on experimental and historical facts in explaining the concepts, theories and laws of chemistry. Moreover, it contains valuable exercises for self-testing, review, and development of knowledge. The volume is well illustrated and contains decriptions of the chemistry experiments performed by pupils in tackling new material and in carrying out practical laboratory assignments.

2. Khodakov; Yu.V., Epshtein, D.A. and Gloriozov, P.A., Neorganicheskaya khimiya, uchbnik dlya 9 klassa (Inorganic Chemistry, A Textbook for Grade IX). Moscow, Prosveshchenie, 1982. (Thirteen edition, revied).

This textbook is similar to the one described in the last entry. The sections concerning the chemical elements and their compounds serve to convey the ideas of the periodic law, the electron structure of atoms, and the theory of electrolytic dissociation. It also goes into the scientific principles on which chemical industries are based and into other aspects of applied chemistry more thoroughly than the textbook for grades VII and VIII. The descriptions of laboratory experiments and other practical exercises call for more independent thinking on the part of the pupil than does the previous textbook.

3. Tsvetkov, L.A., Organicheskaya khmiya, uchebnik dlya 10 klassa (Organic Chemistry, Textbook for grade X), Moscow, Prosveshchenie, 1982. (Twenty-first edition).

The early chapters in this work use the study of hydrocarbons to introduce the basic theoretical issues of organic chemistry, i.e. the theory of chemical structure, the electron interpretation of chemical bonding, and the elements of stereochemistry. These theoretical concepts are then used to present further information concerning the most important classes of organic compounds. The concepts to which the pupil is exposed in working through the textbook include that of the development of substances from relatively simple ones to others which are more complicated, of the existence of genetic links between such substances, of the interaction of the atoms making up a molecule, of the dependence of the properties of substances on their structure, and of the increasing importance of organic chemistry in the development of modrn production. The principles underlying the production of the most typical industrial synthetics are presented along with information concerning the major polymers (plastics, various kinds of synthetic rubber, chemical fibres). Much stress in the sections concerning laboratory experiments and practical exercises is placed on easy-to-perform research tasks and experimental approaches to problem solving.

4. Gol'dfarb, Ya.L. and Khodakov, Yu.V., Sbornik zadach i uprazhnenii po khimii, uchebnoye posobie dlya uchashchikhsya (A Collection of Chemistry Problems and Exercises, An Aid for Pupils). Moscow, Prosveshchenie, 1979. (Second edition).

The collection contains problems and exercises relating to all segments of the secondary-school chemistry course. Each chapter contains problems of varying difficulty, something which enables the teacher to implement a differentiated approach to his pupils. The final section is devoted to compound and more complicated problems calling for a wide range of knowledge and quite mature thinking on the part of the pupil. The problems and exercises can be used by the teacher for purposes of review, as homework assignments, for written and oral testing, and for helping the pupil to prepare for "Chemistry Olympics" competitions. The systematic use of problems and exercises is a highly important means of ensuring that pupils gain profound insight into the subject matter and that they develop their skills and abilities along with an interest in chemistry.

5. Voskresenskii, P.I., Tsvetkov, L.A., Epshtein, D.A. et al., Spravochnik po khimii Moscow, Prosveshchenie, 1974 (Third edition, revised and with additional material).

The handbook is designed for use in connection with chemistry lessons, in out-of-class work, in optional course activities, etc. It contains necessary reference data (some of them are not found in the basic textbook) concerning the general aspects of chemistry, inorganic; organic and analytical chemistry, industrial chemistry and laboratory technique. Work with the handbook encourages the learner to be more independent, to draw maximum benefit from supplementary literature, to use it to find required information, to draw conclusions and make generalizations, and to carry out various types of creative tasks.

6. Kritsman, V.A. (compiler). Kniga dlyachteniya po neoranicheskoi khimii. Posobie dlya uchashchikhsya (An Inorganic Chemistry Reader, An Aid for Pupils). Moscow, Prosveshchenie, 1974 (Part 1); 1975 (Part 2).

This compilation provides additional reading material which enables the pupil to extend and deepen his knowledge of chemistry, as well as to develop his interest in science in general. The sequence of material follows the logic of the curriculum and gives a broad overview of the principal stages of the development of chemistry, of the contributions made by outstanding chemists, and of the advances of modern theoretical and industrial chemistry. The book features extracts from the writings of Lomonosov, Lavoisier, Mendeleev, Arrhenius, Curie, Soddy, and other outstanding scientists of former days, as well as articles by major living chemists, many of them specially commissioned for this publication.

7. Butskus, P.F. (compiler). Kniga dlya chteniya po organicheskoi khimii. Posobie dlya uchashchiksys (An Organic Chemistry Reader, An Aid for Pupils) Moscow, Prosveshchenie, 1975.

This anthology is similar in orientation, content and structure to that described in the previous entry. Considerable emphasis is placed on various issues in theoretical chemistry, modern scientific advances, the achievements of industrial organic synthesis, the description of materials used in modern technology and the future prospects of chemistry and chemical technology in general. The articles present a broad overview of the philosophical side of chemistry and of the relationship between chemical theory and practice. Though simple enough to be readily understood by the young reader, the material is nevertheless presented on a high scientific level.

4.0. BIOLOGY

4.1. Principal trends in the modernization of secondary-school biology in the Soviet Union.

The changeover to universal secondary education in the Soviet Union calls for a new look at the objective of biology courses and at the structure and contents of various biological disciplines. Prior to the changeover, the contents of the biology course for grades V - VII necessarily constituted a "well-rounded whole", setting out the essence of biological phenomena. However, the general level of preparedness of pupils in the grades in question in other subjects, and their usual level of intellectual development, created great difficulties in covering any number of issues and in conveying knowledge concerning the essence of biological phenomena. The changeover, now completed, to universal secondary education has made it possible to structure the course in the shape of a "helix", i.e. a pattern entailing the *gradual* exposition of biological knowledge from grade to grade. The present biology course ensures progressively increasing depth and sophistication of subject matter as the pupil penetrates the essential nature of biological phenomena.

The fact that all young people in the Soviet Union are now required to complete secondary school means that the latter must prepare youngsters not only for enrollment in an institution of higher learning, but also for immediate employment in industry, for active involvement in the life of the country, for the building of a socialist society. This certainly increases the role of school courses in inculcating the liking for hard work and in the occupational counselling of young people. In this connection the biological disciplines have a particularly important role to play in familiarizing young people with any number of occupations involving biological systems whose manpower needs are already great and bound to increase still further. In addition to fundamental knowledge, there is an increasing need for applied knowledge and skills. It is therefore increasingly important to acquaint pupils with the applications of biological theories, with biological patterns as they impinge upon the national economy, with the most advanced technologies in agriculture and other branches of production in line with the current level of scientific and technological progress.

More than ever before, the teaching of various subjects under the general heading of biology has as its objective the training and preparation of young people to deal with environmental protection problems. Global changes in nature under the influence of human activity accompanied by the transformation of the natural environment so as to threaten life on earth makes it particularly important to provide environmental education and training of young people. Pupils today must be taught the scientific principles of nature protection and gain a deep understanding of the need to respect nature and to use natural resources with care.

The problem of environmental education is closely related to the study of hygiene. Pupils must systematically learn about the structure and vital activity of the human organism, and particularly the higher nervous system. Socialist schools are called upon to ensure the all-around spiritual and physical development of young people, who must be made to understand the harmful effects of environmental pollution, alcohol consumption, smoking, etc. on their bodies.

In accordance with the decree of the Central Committee of the Communist Party of the Soviet Union entitled "Concerning the Further Improvement of Ideological and Political-Educational Work", soviet schools today must strive to "achieve the organic unity..... of a scientific world outlook, high moral and political qualities, and love of work. Young people must be imbued with an interest in political knowledge; everything possible must be done to develop their active interest and involvement in the life of society"[1]. This means that school biology courses are called upon to play an increasingly important role in the shaping of the ideological-political views and convictions of pupils, and in the realization by pupils of the tasks set by the

1. Kommunist, No. 7, 1979, p. 19

Communist Party and Soviet Government in the field of biology, agriculture, medicine and public health. Moreover, pupils must be taught and encouraged to take an active part in coping with these tasks. Our age, with its rapid development of science and technology, is marked by the rapid development of new theories and advanced technology. At the same time it is characterized by the advent of any number of anti-scientific, reactionary currents which exercise a negative influence upon young people. All of this heightens the role of school courses in biology in the presentation of the dialectical-materialistic essence of biological phenomena, in the exposure of the unsoundness of religious views on the origin of life of plants, animals and human beings, on the adaptation of organisms and the origin of new species, on the nature of sleep and dreaming, etc.

The preparation of young people for active participation in the life of the country for work or for entry into an institution of higher learning confronts the school and the biology course in particular with the task of helping the young person develop to apply creatively newly-acquired knowledge and skills, and to manifest creativity in dealing with learning problems. Particularly timely in this connection is the task of developing pupils' capacity to study independently and to find their way around the sea of scientific and political information with which the world is awash. The amount of knowledge which every person must possess in our age of the scientific and technological revolution has increased considerably, creating a great demand for people with a creative intellectual bent whose development and encouragement is in large-measure the responsibility of the school.

4.2 Improving secondary-school biology studies on the basis of didactic principles.

Biology courses offered in Soviet secondary schools are currently being improved by better defining the educational, training and developmental components of the learning process as a whole. To a large extent, the forms assumed by the components depend upon the contents and the system of biological knowledge presented, and on the sequence and depth of subject matter apportioned among the succesive grades. Hence, the choice of contents, the presentation of the basic principles of biology and their reduction to a system of biological knowledge may be considered as the most topical and typical problem to be dealt with today. Living nature is highly varied, comprising hundreds of thousands of species of plants, animals, fungi and single-celled organisms which inhabit the earth in the form of relatively isolated groups (populations and ecological communities of various types known as *biocoenoses*) constituting, together with the componants of inanimate nature, the complex system which we call the biosphere.

Biological science is concerned with the morphological-functional organization of individuals, populations, biocoenoses and the biosphere, as well as the phenomena in which they are involved and the patterns which the exhibit (the ontogenesis of individuals and the evolution of supraorganismic systems, as well as the changes which these undergo under the influence of human activity). Thanks to the efforts of scientists the world over, biology has achieved enormous success in helping man to understand life on the molecular-physiological level and at other levels of organization. The development of the biological sciences is proceeding towards the increasingly differentiated study of phenomena and objects in living nature, towards greater insight into their essential character, as well as towards the generalization of factual knowledge and theory.

The increased volume of scientific information available dictates a selective approach to basic scientific facts, concepts, patterns and theories for inclusion in secondary-school biology courses. This is necessary in order for pupils to be able to shape a complete picture of the biological world, while at the same time having their skills in the use of theoretical knowledge for the scientific-materialistic explanation of processes and phenomena in living nature, for the formulation of philosophical conclusions, for the well-argued criticism of anti-scientific reactionary and religious views as regards living nature, for the scientific justification of progressive technologies in these branches of production which rely on biological systems, and finally for the development of creative faculties.

Concomitantly, the limited amount of time available in schools for the study of biology, the well-defined level of mental development and general preparation of pupils in other subjects, and the need for increased attention to personality development and maturation dictates the need for strict selection of scientific knowledge about living nature as presented in secondary-school biology courses.

The development of biology education is presently directed towards the stricter selection of facts and phenomena from the increasing volume of biological findings accumulated within the science of living nature, the solution of increasingly complicated problems of education, upbringing and development of pupils, and the preparation of young people for participation in material production.

These tasks can be dealt with only by stricter selection of secondary-school biology course contents, the integration of knowledge around a limited number of guiding ideas, the specification of the depth to which concepts should be exposed, and the elaboration of methodological pathways to ensure their accessibility. The contradiction in question has been dealt with to some extent at various stages in the development of secondary-school biology. Thus, towards the end of the 1960s the content of biology courses in Soviet schools was reviewed considerably to bring it into line with the achievements of the science of living nature.

The streamlining of secondary-school biology courses involves the integration of knowledge on the basis of certain basic ideas in biology. The integrating function in secondary-school biology courses is performed by the concept of evolution, which constitutes a broad generalization of knowledge concerning living nature. The development of biological science over the past few decades has made it possible to develop a no less important generalizing idea, namely that of the levels of organization of living nature. This notion likewise plays an integrating role in the selection of biological course contents and their structure. Thus, the theory of evolution and levels of organization of living organisms are the basic ideas which serve to integrate knowledge about biology within the school course. It is these guiding concepts that have been applied in selecting factual material from the disciplines of morphological anatomy, taxonomy, physiology, genetics, ecology, etc. In addition to the integrating ideas of biological science, the selected course contents make allowance for certain basic didactic principles (accessibility of subject matter to pupils of a given age, the level of their mental and emotional development, their level of preparation in other subjects, the scientific rigour of the course contents in question, etc.). Didactic principles introduce certain correcting factors into the selection of "guiding ideas" for inclusion in the curriculum and into its breakdown by grades.

The attempt to use integrating ideas without allowance for didactic principles results in the violation of the principle of accessibility. The theory of evolution is one of the most complicated in all of science, for its mastery requires considerable preparation and training in biology. Before turning to its study, pupils must be familiar with the structure and vital functions of living organisms and biological systems (populations, species; biocoenoses) within whose context evolution transpires. Lack of knowledge of organismic life forms precludes the presentation of the notions of population and species at the required level of scientific rigour; lack of proper understanding of the latter concepts makes it difficult in turn to explain the notion of a biocoenosis. Understanding of populations constitutes a basis for undertanding the evolution of the organic world whose alteration takes place within the "depths" of a population acted on by various ecological factors and other influences within a given biocoenosis. Hence, in accordance with the logic of science, the presentation of the theory of evolution must be preceded by an understanding of the structure and function of organisms and supraorganismic systems (populations, species, and biocoenoses). Observancce of this sequence is justified by didactic principles: it is easier for pupils in grade V to grasp the structure of functions within an individual organism than those of a population and species, let alone the concept of evolution, whose mastery requires the ability to think in abstract terms. This is why in structuring biological knowledge it is necessary to proceed from the methodological concept where knowledge develops from the familiar (flowering plant in the grade V biology course) to the less familiar (the lower plants in grade VI); from simple material requiring thinking in terms of images to more complex material (from the morphology and anatomy of an organ to its physiological processes; from the description of cell structures to the process of cell metabolism and cell division; from phylogenetic links to the reasons for genetic kinships between taxons), with allowance for the required level of complexity of the subject matter, age-related abilities, the overall level of development of the pupils. (The study of metabolism in grades V - VII is largely descriptive and on the level of an individual organ and organism, whereas in grade X it is taken up in energy terms on the molecular-cytological level.).

However, the stucturing of biological knowledge carried out in the 1960s was not sufficiently rigourous in the sense that the principle of accessibility of knowledge presented in school courses was not always adhered to. This explains why the contents of the school biology course had to be reviewed once again towards the end of the 1970s in order to ensure a stricter selection of scientific facts and concepts, more rigorous definition of the depth in which these might be presented, and clearer determination of their role in the education and development of pupils.

This most recent review of the contents of secondary school biology courses was undertaken with allowance for the need to integrate knowledge on the basis of certain major biological concepts and methodological precepts, namely:

- correspondence of subject matter to the time available for its study;
- correspondence of subject matter to the overall level of preparation of pupils and their ability to assimilate information (the principle of accessibility);
- correspondence of subject matter to the level of development of the science in living nature;
- appropriateness of subject matter to the more effective shaping of a holistic biological world picture, i.e. a world outlook in line with the tenets of dialectical materialism, with proper atheistic attitudes, a well as with correct attitudes to hygiene, the environment, work, morality and choice of occupation;
- correspondence to the tasks of the gradual buildup of knowledge with the establishment of appropriate links between biological disciplines, so that individual courses might constitute a single well-rounded whole, etc.

Special emphasis was placed on the criteria of accessibility, correspondence of subject matter to the time available, and the general level of preparation and knowledge in other subjects. It was on the basis of these criteria that school biology courses were subjected to thorough analysis. The purpose of this review was to maintain the most important concepts while at the same time establishing a more precise definition of the depth to which they were to be presented. The criteria set out above were used to exclude from certain courses particularly complicated issues not readily understandable to the pupil. For example, the course for grade V no longer includes such topics as photosynthetic energy, the mechanism of double fertilization of flowering plants, the fundamental biology of mitosis, etc., all of these being complex questions whose understanding requires considerable preparation on the part of the pupil. Pupils in grade VI are simply not able to grasp histological data concerning genetic kinship between classes of protozoa and such matters as the biological basis of conjugation and metabolism. Any number of such topics have been excluded from the biology courses for grades V and VI, or else presented in simplified form (mitosis). The same issues are covered on a higher scientific level in the higher grades. The law on universal secondary education provides for the mastery by pupils of the entire system of biological knowledge required to shape a complete biological world picture.

In addition to these extremely complex and difficult-to-understand issues, we have also seen the exclusion of less significant secondary material of a specialized nature which does not effect the shaping of the required body of knowledge and whose elimination does not lower the scientific level of the course. Thus, the grade V course no longer includes certain not very important data concerning the variety of types of leaves, stems, fruit and seeds; in grade VI and VII the number of animals studied has been reduced; in grade VIII it is information concerning the production of medicines which has been let out; examples of the adaption of organisms are no longer covered in grade IX; grade X pupils are no longer concerned with the details of cell organoids and the processes occurring in them. And so on.

This streamlining of school biology courses has not lowered their scientific level in any way. Quite the contrary, the improved course content now allows for the presentation of the latest advances in such important branches of biology as ecology, evolutionary theory, genetics and cytology. Pupils familiarity with the basic issues in each of these disciplines is necessary for shaping of a dialectical-materialistic world outlook and of appropriate ideological and political views, as well as for achieving a better grasp of ecological issues. The improvement of the biology curriculum just outlined was accompanied by a raising of the scientific level of each course through the more complete and consistent presentation of various aspects of ecology, the theory of supraorganismic systems, physiological theory, as well as hygiene, modern problems in genetics, and current isues in the theory of evolution.

4.3. The Contents and structure of secondary-school biology

The application of the above set of criteria in redefining the contents and structure of secondary-school biology courses led to the conclusion that the traditional structure of the subject as a whole should be maintained. In accordance with this structure, the study of biology begins with a consideration of the system of biological knowledge concerning the individual organism. In turn, knowledge about the latter is presented on the basis of the structural-functional approach: the anatomical-morphological specificities of the plant world, the later of the animal world and the human organism, are presented in close interrelation with their functioning. At the same time, the structure and functions of the organism are considered in connection with habitat and environment.

Let us consider the role of integrating ideas and didactic principles in the selection of course content and structure. Traditionally and with full justification, the study of biology begins with the consideration of the structural characteristics and vital activities of the plant organism. Reasons for this include the fact that plants are found everywhere in nature, that they can be grown in the biology laboratory or in special experimental patches near the school, the possibility of running experiments on plants, using plants in the classroom as handout material, and the possibility of observing them in nature to monitor their interrelations with the habitat. In addition, there is the possibility of using plants in practical exercises involving the application of theoretical knowledge concerning the vital activities of plants in the course of their cultivation.

The familiarization of pupils with the structural attributes and vital functions of the plant organism, and later with the principle taxons of the plant world constitutes the first stage of training based on the theory of concept development. This consists in the gradual introduction of general biological concepts, which are then developed from grade to grade as the pupil works his way through the biology course. The study of the plant organism in grade V and of the principal taxons, plant communities and phylogenetic links and stages in the historical development of the plant world in grade VI makes it possible to present such important general biological notions as those of morphological anatomy, cytology, physiology, ontogenesis, ecology, systematics, and evolution, with maximum reliance upon direct observation and handling of real plants in nature.

On the basis of the study material presented in grade V and VI, pupils are given a grasp of such philosophical concepts as that of the integrity of an organism, the interrelationship between structure and function, as well as between an organism and its habitat, cause and effect, and the link between theory and practice. At the same time pupils develop a respect for the world of living things around them, coming to appreciate their significance in nature and in human existence, and therefore the need to protect the environment.

On the basis of these principles, pupils in grade V are able to learn about the structure and functioning of a plant organism, its interrelations with its habitat and the integrity of each given biosystem. They also receive agrotechnical information concerning the cultivation of various crop plants.

The study of the biology of a plant organism begins with the most common species readily accessible to the pupil. Of the roughly half a million plant species which exist on our planet, nearly one-half are flowering plants adapted for life in the most varied conditions. The majority of these species exhibit all of the organs of the plant organism in well-developed form and display a broad variety of vital processes. All of this dictates the desirability of beginning the study of biology with a consideration of the structure and functioning of a flowering plant, its individual development, and its interactions with the habitat.

The sequence followed in studying the structure and functions of plant organs is based on the idea of levels of organization of living things. This is why the presentation of the structure and functions of organs is undertaken only once the pupil has grasped the necessary background information on the cell as the smallest structural-functional unit of any organ and on the cell as the primary building block of the plant organism. Without such knowledge pupils would have difficulty in understanding the various aspects of the structure of plants and the vital processes occurring within them. The improvement of biology course content involved simplifying the treatment of cytology in grade V. Today pupils begin studying the cell on an elementary level: they find out that a cell has a wall, a nucleus, cytoplasm, vacuole and plastids, after which they are provided with brief information concerning the functioning of each of these components. The vital activities of the cell are illustrated by considering the movement of cytoplasm and the entry of substances into the cell, although the mechanisms involved in these processes are not taken up. The process of cell division is dealt with in a very cursory way in order that pupils might gain a firm grasp of its essence, namely the uniform distribution of chromosomes among the daughter cells; this is done without going into the phases of division or the cell structures involved in the process. The same topic is taken up on a more profound (molecular) level in the final year of the biology course, i.e. in grade X. Universal and obligatory secondary education in the USSR provides for the study of cytology in particular, and biological processes and phenomena in general, in sufficient scientific depth.

Once the fifth graders have learned about cell structure and the processes going on within the cell it is a matter of simple logic to acquaint them with the structure and functions of plant organs. Nevertheless, this unit is preceded by one concerning the plant seed, which contains many plant organs in embryonic form. Familiarization of pupils with the development of organs out of a seed is directed at explaining the development of an individual plant, the species involved in the growth and development of each organ as it interacts with its environment, and the agrotechnical aspects of seed planting and germination.

The development of understanding of the structure and vital activities of plants is assisted by the study of the plant organs (roots, stems, leaves and flowers) which are involved in the feeding and reproduction of plants, their intraction with the environment, and their growth and development. The process of formation of organic substances under the action of solar energy, the uptake of water and minerals, and the movement of substances within the plant are all covered in an elementary, descriptive way, inasmuch as pupils in grade V do not have the necessary background in chemistry and physics to permit them to go into the physico-chemical basis of these biological processes. Another unit now reworked into simplified form is the one concerned with photosynthesis. The grade V biology course no longer deals with the accumulation of energy in the process of photosynthesis, experience having demonstrated that this topic was inaccessible at the stage in question. On the other hand, it is covered in grade X, where the chemistry and energy aspects of photosynthesis are thoroughly covered. It is also at this higher level that pupils study the mechanism of uptake of substances by the cell, as well as phagocytosis and pinocytosis.

The concluding unit of the grade V biology course concerns the plant organism as a complete self-contained system. This topic provides an opportunity for generalizing knowledge about individual organs and the processes occurring in them and for studying the ways in which individual organs interact with one another. At this stage the pupils become familiar with the basic vital functions of the plant organism as a whole, as distinct from the functions of its individual organs. The interrelation of a plant with its environment is also studied. The knowledge of the structure, vital activities, ontogenesis and ecology of the plant organism acquired by pupils in grade V serves as a basis for the study of supraoranismic systems, the plant-world system, and the evolution of the plant world in grade VI. The treatment of the structure and life of flowering plants in grade V provides background for an elementary understanding of supraorganismic systems (species and other taxonomic

categories) through the classification of flowering plants. The mastery by pupils of materials concerning the classification of flowering plants in turn constitutes an important didactic prerequisite for the study of the principal plant orders of increasing complexity. In other words, the idea of evolution is used to advantage in the structuring and sequencing of topics in this part of the course, when pupils begin to develop a notion of phylogenetic links between the major taxons and of the historical development of the plant world. One of the concluding units of the plant biology course, entitled "The development of plant life on the earth", serves the purpose of securing the generalizing the pupil's understanding of evolution.

The study of the peculiarities of structure, feeding and reproduction of plants in each taxonomic group makes it possible to shed light on its place and role in living nature, to develop an under-standing of ecology, to explain the ways in which biological knowledge is useful to the national economy, and to put the principle of polytechnical education into practice.

The first stage of learning about evolution and levels of organization is rounded off by the study of the largest of the supraorganismic systems, namely the plant community. This unit familiarizes pupils with the place of various plant taxons within the plant community by having them establish links between them on the basis of alimentation, habitat and role in the plant community. The study of the plant community is predicted on the understanding by the pupil of all previously covered material. The final unit is intended to make this understanding general, thus enabling him to see the unity of the plant world notwithstanding its extreme variety, and to appreciate the need for its protection.

Furthermore, the study material concerning the plant community has now been brought into line with the latest advances in biology. Among other things, the pupils learns about food chains linking animate and inanimate nature on the one hand and plants and animals on the other. The meaning of ecological concepts is explained on the basis of local biogeocoenoses, whose study under natural conditions makes it possible to convey the appropriate information in a form readily accessible to the pupil.

In the second stage of biology studies the pupils become acquainted with the animal-world system, learning about the basic types of invertebrates and the principal classes of vertebrates, about the structure and vital activities of the most widespread organisms of practical significance to man, and about the most typical representatives of various taxonomic groups. They build up knowledge concerning the reproduction, development and environment of these animals, as well as their role in natural and the human ecology. Darwin's theory of evolution is taken up on an elementary level and used as a basis for generalizing knowledge concerning the living world and for examining the causes of phylogenetic links.

The transition to zoology may be regarded as the second stage of development of the principal concepts of biology. Having already mastered a system of biological notions through the study of the plant organism, the plant world and its evolution, and plant communities, the pupil is prepared to make more effective and consistent use of the notions of evolutions and levels of organization embodied in the recently reworked and restructured zoology course, and thus to grasp general biological concepts at a higher level.

Pupils' notions concerning the evolution of the plant world serve as a basis for the study of the structure, vital activity, reproduction and development of animals belonging to various systematic groups in an ascending order and for the establishment of phylogenetic links between taxons. The ordering of subject matter within each unit on the basis of the phylogenetic principle makes it possible for the biology pupil to perceive genetic links between classes within each individual taxon, to establish for himself the levels of organization of animals, and to identify the stages whereby the animal world becomes increasingly complex, with lower forms evolving into forms exhibiting ever greater levels of complexity.

Elementary knowledge about the plant cell already in the possession of the pupil enables him to embark upon the study of animals beginning with single-celled organisms. This knowledge is then expanded through the study of organs and systems of organs of many-celled animals. This is coupled with increasing understanding of supraorganismic systems such as species and natural communities. It is at this stage that pupils learn about the morphological-anatomical and ecological distinctions among the representatives of various taxonomic groups, and come to appreciate the immense variety of animal species.

The continuity of subject matter in the study of zoology, its presentation in an appropriate logical sequence, are ensured not only by adhering to the phylogenetic principle, to the concept of evolution and levels of organization, and to appropriate didactic criteria, but also by orderly presentation. Within each unit devoted to this or that taxonomic group the pupils learn about the internal and external structural features of the living organism by studying a typical representative of the given taxon and becoming acquainted with its vital activities, reproduction and development in relation to the environment and adaptation to life under a given set of conditions. This teaches significance of particular species in the national economy, enabling a pupil to draw conclusions concerning the need both to regulate and protect animal populations.

The concluding units devoted to animal communities permit the generalization of knowledge about animal organisms, about the variety of species comprising various taxonomic groups, and about their place and role in nature. This makes it possible to familiarize the pupil with a supraorganismic system more complicated than that of plants and to establish food links between animals belonging to different species on the one hand and between plants and animals on the other. At the same time the unit provides an overview of the natural community as a complete and integrated system which requires protection in order for its completeness and integrity to be maintained.

The grade VII biology course is rounded off by a unit concerning the historical development of the animal world and elements of Charles Darwin's theory of evolution. Mastery of the notions of evolution by the pupils serves as a basis for learning about the genetic kinship between types and classes of animals. At the same time, the unit provides an opportunity for presenting a materialistically oriented explanation of the origin of various types of animals and for the shaping a view of the origin of the animal world which is grounded in the tenets of dialectical materialism.

Pupils' knowledge of the structure, functions, reproduction and development of the animal organism, of the evolution of the plant and animal worlds, of cell structure and the cell structure of plant and animal organisms prepare them for learning about the structure and vital activities of the human organism. This is why the study of human anatomy, physiology and hygiene in grade VIII constitutes an extension and deepening of knowledge concerning the life of organisms, including the similarities and differences between animal and human biology.

The contents and structure of the course are to a large extent determined by evolutionary theory, which makes it possible to deal with the structure and functions of human organs and systems as a consequence of the development of the animal world marked by the formation of higher nervous activity and the transition from the biological form of the movement of matter to the social form. The course material also continues to develop insight into phylogenetic links in the study of the structure and functions of the human organism as its genetic kinship with animal organisms is amplified. At the same time, the principal distinctions between man and the animals dealt with in terms of the role of work, language, and consciousness in shaping man as a social being are discussed.

The biology course at this stage entails the study of the structure and vital activity of the human organism at the level of cells, tissues, organs and systems of organs. The information concerning the variety of cells, their structure and their functioning becomes increasingly complicated: the pupil comes to learn about various organoids, their functions, and the vital activities of the cell. At the same time, pupils' lack of background in organic chemistry precludes studying intracellular processes on the molecular level, so that these have to be treated descriptively. Nor is it possible to develop the notion of supraorganismic systems - a fact which disrupts course continuity and raises the problem of defining more precisely the place of the course in secondary school biology as a whole.

In the final two years of biology, i.e. in grades IX and X, it is the ideas of evolutionary theory and the levels of organization of the living world which have the greatest bearing on the content and structure of the subject matter presented. This is due to the fact that the psychological faculties of pupils are by now sufficiently developed, as is their understanding in other fields. The organic world is now studied at various levels of organization (those of cells, organisms, species populations, biocoenoses, and the biosphere). At the same time the last two years of biology do not allow for the step-by-step presentation of structure and function at all levels, beginning with the cell and ending with the biosphere. Grade IX pupils have not yet been exposed to organic chemistry. It would therefore be difficult for them to grasp the issues of molecular biology, rendering it undesirable to begin the final stage of the biology course with the study of the cell. Even though the course reflects all of the levels of organization of living nature, the order in which these are taken up does not reflect their ranking or subordination in nature.

The role of evolutionary theory in shaping the final two years of secondary-school biology is even greater than with the earlier courses. In fact, the course *begins* with a study of the history of the concept of evolution. The biology course in grade IX is centred on the theory of evolution and the motive forces, direction and results of evolution. Pupils' familiarity with this theory makes it possible to draw upon it in elucidating the causes leading to the establishment of various biosystems and in establishing relationships between individual course units. The theory of the levels of organization of living nature allows the clearcut delination of the patterns characterizing various biosystems, i.e. it makes it possible to focus pupils' attention on the laws and regularities of metabolism at the cellular level, of ontogenesis, of genetic inheritance and variability on the level of organisms, and of the development and interrelation of populations, which in turn constitute the supraorganismic system known as the biocoenosis.

The mastery by pupils of information concerning the motive forces underlying evolution is a prerequisite for their grasping the mechanism whereby specise arise, the various factors involved in the adaptation of organisms to their environment, the pathways of man's evolution, the origin of life on earth, and the changes which occurred in biological systems within particular periods of geological time. Knowledge concerning the motive forces of evolution likewise constitutes the basis of a proper understanding by pupils of the dialectical-materialistic view of nature.

The theory of the factors and directions (pathways) of evolution helps to integrate the contents and structure of the study units concerned with the development of the organic world and the origin of man. It facilitates the selection of factors used to characterize the changes in the plant and animal worlds in various ages and periods, making it possible to focus attention on the principal aromorphoses in the development of plants and animals and epimorphoses in the evolution of man, with a proper understanding of adaptive radiation ensured by the use of the most striking examples available.

Thus, pupils in grade IX become familiar with such supraorganismic systems as species and populations. The presentation of the process of evolution in fact relies on knowledge concerning biocoenoses, although no explicit definition of the latter concept is given. It is at this level that pupils learn about Darwin's theory and about the variation of populations and species over long periods.

Once pupils have mastered the theory of evolution in its classic form (with genetic inheritance and individual variability treated in a descriptive way and the notion of the gene introduced on an elementary level), it is quite logical to turn to the study of cytology early in grade X. It is at this stage that pupils embark upon the study of organic chemistry, becoming familiar with the theory of the structure of matter and with functional groups. This facilitates their understanding of topics in molecular biology.

The study of cytology helps to deepen youngsters' knowledge concerning the organismic form of life and to gain insight into such vital processes as respiration, the assimilation of substances by cells, photosynthesis and protein biosynthesis, shedding light on the mechanisms of energy supply to the cell and on the biological essence of the reproduction and individual development of organisms. Familiarity with the elements of cytology provides a proper groundwork for the study of the origin of life and the development of the cellular organization of the organism. Once pupils have understood the structural-functional organization of the cell, they are prepared to see that the material basis of reproduction and ontogenesis are the processes of DNA replication and protein biosynthesis on the cellular level. The processes of meiosis, fertilization and mitosis lie at the basis of the transmission of genetic information in the course of ontogenesis, constituting the material ground of hereditary links between generations.

A logical extension of the deepening of knowledge about the organismic forms of life are the notions of genetic inheritance and variability as universal properties of organisms manifested in the process of individual development. The presentation of the basics of genetic inheritance is predicated on pupils' understanding of such processes of molecular biology as DNA replication, mitosis and meiosis. At the same time their exposure to genetics and cytology provides the necessary basis for a review of evolutionary theory with allowance for the latest advances in biology. The newly acquired knowledge concerning genetics and evolution is in turn used to familiarize pupils with the chief methods, trends and advances in the breeding of plants, animals and microorganisms.

The concluding units provide an opportunity for deepening and generalizing knowledge concerning supraorganismic systems, i.e. species, populations, biogeocoenoses, agrocoenoses and the biosphere. The fact that pupils are by now equipped with knowledge concerning various ecological systems, the interrelations which exist within them, the circulation of substances and energy flows within biocoenoses and in the biosphere enables them to understand the reasons for the dynamic stability of specific biosystems, for the need to protect nature and for the need to plan human activities with due allowance for ecological factors.

Thus, the system of knowledge and the sequence followed in developing an understanding of general biological principles is largely based on the actual structure of the discipline and on the gradual deepening of understanding from grades V through X. In accordance with the principle of systematicity, pupils are exposed to a gradual developing set of biological concepts: their understanding of the organismic forms of life and of supraorganismic systems is developed both within each yearly segment of the biology course and over the course as a whole. At the same time, it is evident from the foregoing account, the sequence in which knowledge about the levels of organization of the living world might be presented is occasionally altered in the light of didactic principles.

4.4. Highlighting essential knowledge and skills as a means of improving secondary-school biology.

The modernization of secondary-school biology in the Soviet Union has been effected by stressing essentials along with the required auxiliary subject matter. The differentiation of contents was facilitated by including a section entitled "Basic pupil knowledge and skills requirements" in the curriculum. This sets out the bodies of knowledge to be mastered in each grade and indicates their significance. The introduction of this "yardstick" section helps to see to it that the appropriate material is indeed mastered by the young learners. The essential body of knowledge consists of biological theories, laws and patterns (regularities), and concepts which have to be securely grasped by each pupil, sometimes to the extent of his being able to make use of such theories and regularities in an operational sense.

Particular emphasis is now placed on concepts which pupils must master in elementary form. This applies particularly to those which have to do with the vital activities of plants and animals. The learning process must be structured with due regard for the difference between that which is primary and that which is secondary, with the stress being laid, needless to say, on a proper grasp by pupils of information and knowledge of the former category.

Thus, the "Basic requirements" for grade IX specify that pupils must become familiar with the essentials of Darwin's theory of evolution of the organic world and be able to apply Darwin's theory to explain the processes of species formation, adaptation, and the derivation of varieties and breeds, as well as to criticize religious-idealistic views of the origin of species and the adaptation of organisms. For this reason, emphasis from the start is placed on the forces behind evolution as pupils set about studying units devoted to "Darwinism". All of the components of the forces which propel evolution are thus dealt with from the very first lesson onwards. It is in the very first lesson that pupils discover that evolution constitutes a complex of factors, namely genetic variability, the struggle for survival and selection. In subsequent lessons each of these components is taken up separately, with pupils learning about the types of variability. It is at this stage that genetic variability is singled out and its role in evolution demonstrated. Subsequently, in studying the struggle for survival (survival of the fittest), the emphasis is not so much on the various forms of struggle for survival as on the role of this factor in evolution: all forms of struggle for survival are thus presented from this standpoint.

In dealing with the struggle for survival the pupils are shown the link between this factor of evolution and genetic variability, while the units concerned with natural selection highlight the interrelationship of all evolutionary factors, even though the pre-eminent role is assigned to natural selection.

But this in itself does not complete the study of the cardinal concept of the motive forces which drive evolution forward, for the pupil is gradually trained to apply his knowledge in explaining evolutionary changes in nature. This is why the presentation of the origin of adaptations and of species differentiation entails explaining the role of all of the evolutionary factors involved in the shaping of the features of adaptation (adaptedness).

The ability to apply Darwin's theory in providing a materialistic explanation of biological phenomena is likewise enhanced through the study of species formation. In studying this aspect of biology pupils become convinced that only the joint action of all of the factors involved in evolution makes the process of species formation possible.

Darwin's theory of evolution is brought to bear on the study of species formation in the following way. The pupil learns that

- favourable conditions make for the intensive reproduction and extension of the habitat of the initial species;

- groups of individuals of the initial species (populations) become isolated due to a number of physico-geographical factors (such as the formation of physical barriers in the form of mountains and bodies of water and the advance of glaciers);

- genetic changes continually arise in populations and are transmitted through them through interbreeding;

- the struggle for survival and natural selection are responsible for the preservation and generational survival of individuals displaying useful heriditary changes which increase the chances of such survival in the environment inhabited by the population;

- in the course of many generations the population changes so much that it is no longer capable of producing offspring with individuals from other populations of the initial species, whereupon it can be regarded as a separate species.

But the pupil's study of the motive forces of evolution is not confined to the unit relating to "Darwinism". It is also one of the principal elements of the units on the "Development of the organic world" and "Origin of man". When covering the unit entitled "Development of the organic world" the theory of the motive forces of evolution is used to explain historical changes occurring in living nature, i.e. the development of the organic world by way of aromorphoses and idioadaptations.

The notion of the motive forces of evolution is further developed in covering the unit on the "Origin of man", which provides an opportunity for highlighting the social factors of evolution in addition to the biological.

Hence the pupils not only learn about the motive forces of evolution, but also become skilled in using them to explain biological processes and to criticize idealistic views concerning the origin of species and adaptation.

The modernization of secondary-school biology was aimed at stressing a range of special practical, intellectual and general-educational abilities whose functional mastery by the pupil was to be a measure of his understanding of the subject matter.

The curriculum specifies a range of practical skills enabling pupils to set up experiments on plants in order to study their vital processes, to conduct observations and to draw conclusions from experimental data. The curriculum contents include a broad range of biology experiments which pupils are called upon to perform in covering specific topics. The setting up by pupils of experiments as they develop, the use of experiments to identify the nature of biological phenomena and processes, and the formulation of appropriate conclusions helps pupils to become skilled experimenters. The fact that the curriculum spells out requirements concerning experimentation on living objects with the aim of helping the pupil discover the essence of biological processes along with the fact that criteria are now available for assessing such skills, means that the latter must be duly emphasized in the appropriate lessons. Hence, the methods followed in carrying out biology experiments must be oriented not only towards the explanation of basic concepts by way of experiments, lectures by the teacher, and independent work on the part of pupils, but also at the mastery of actual experimental skills in the school setting. Experimentation as an investigative technique thus constitutes an important component of the biology course.

The practical-skills requirements specify that pupils must be able to conduct observations and to describe what it is they are observing. In other words, they must become articulate about such matters as the bursting of buds, flowering, the formation of seeds and fruit, the changing colour of leaves, leaf shedding, the variability of plant and animal features, signs of adaptedness, the results of natural selection, etc.

In addition, they must be able to make observations on themselves and to draw conclusions about such observations. In view of these requirements and criteria concerning pupils' skills as observers, biology lessons and field trips include observation activities as a routine component, while lessons in human anatomy, physiology and hygiene involve keeping watch over one's own organism. Just like the school experiment, observation becomes a part of learning whose techniques pupils must master in order to obtain information on living nature and to develop the knack of "imaging" events and processes occurring in the living world.

Another set of skills which pupils are called upon to master has to do with the use of microscpe. This important tool enables them to see at first hand the enormous variety of plants and animals invisible to the naked eye, to study organisms on the microstructural level, and to enrich memory by visual perceptions. At lessons devoted to cells, tisues and micro-objects (bacteria, single-celled algae, protozoa) pupils learn to use a variety of magnifying devices, employing them to acquire new knowledge.

The curriculum likewise calls for the equipping of pupils with the ability to recognize plants with the aid of identification cards, naming the principal plant species belonging to the appropriate families, and identifying animals studied as belonging or not belonging to a local species. The lessons whereby such skills are developed have an important place in school biology courses. For example, in dealing with the topic "Flowering plants and their classification" and with many of the units concerned with the variety of animal species, pupils are not only taught the fundamentals of plant and animal classification, but also trained in the recognition of various forms of plants and animals.

The above skills are polytechnically oriented, and their mastery is certainly a useful adjunct to subsequent learning and work activities.

The general biology curriculum likewise prescribes that pupils must acquire the ability to cope with elementary problems in cytology and genetics. Such an ability is regarded as a means of ensuring better understanding of topics in these fields as well as of promoting independent learning. This is why problem-solving is a part of lessons in cytology and genetics. The fact that pupils are asked to solve problems in molecular biology and genetics means that they are better able to fill in gaps in their understanding of the cytological basis of heredity.

45. Augmenting the role of secondary-school biology in ecology education and training.

The modernization of secondary-school biology as taught in Soviet schools involved increasing its ecological (environmental) orientation and updating course contents to bring them into line with the latest advances in ecology. The need for this was dictated by the necessity of increasing public awareness of environmental issues in the age of scientific and technological progress. All of this in turn requires a systematic presentation of the fundamentals of nature protection as an integral part of the biology course. It is with this end in mind that the biology course was made to incorporate a clearer and better-structured presentation of the variety of plants and animals, of the factors affecting their numbers, of the measures implemented to protect various species, and of the nature protection laws adopted in conformity with the appropriate article of the USSR Constitution.

For example, the grade V biology course introduces the notions of the plant world as an integral part of nature and of the proper use of natural resources and their reproduction, while the study of photosynthesis provides an opportunity for explaining the need to control air pollution, to protect flowering plants, and to prevent the large-scale gathering and picking of wild plants and flowers.

The grade VI biology programme deals with the effects of economic activity on the variety of flowering plants, with the protection of rare plant species, with the contents of the endangered-species list known as the Red Book, with the effects of human activities on plant communities, with the way in which the USSR Constitution deals with the tasks of nature protection, and with the role of wilderness areas, botanical gardens and nature parks in the study and rational use of plant life and rare-species protection.

Pupils in grade VII learn about the practical and aesthetic value of insects and the need to protect the variety of insect species. Another topic is the effect of human activities on fish populations and the need to make rational use of fish resources. Here pupils learn about the problem of human impact on bird populations, about the importance of wilderness areas, sanctuaries and zoological gardens in preserving rare bird species, and about the effect of human activities on the numbers and species variety of mammals and on the character of measures taken to protect them. Young people at this level learn not only about natural communities and the forms of interaction occurring within them, but also about the consequences of human activity for natural communities. These studies entail learning about nature protection measures as much, as well as with the contents of various national endangered-species lists and nature protection laws.

In studying human biology in grade VIII pupils learn about the hygiene aspects of environmental protection, becoming familiar with the harmful effects of pollution (including noise pollution) on various organ systems, as well as with measures directed at controlling such pollution.

In grade IX pupils become acquainted with the effects of economic activity on the structure and reproduction of populations, with the problems involved in the rational use of species and the preservation of species variety, and with human activity as a powerful influence on living nature.

The grade X biology course gives pupils an opportunity to learn about the pollution of the environment by mutagens and about the significance of breeding in the preservation of the species variety of the organic world. The youngsters learn, among other things, about the methods used to assess and regulate population size. The final unit is devoted to the interaction between nature and society and to ways and means of protecting the natural environment (pollution control, the preservation and conservation of natural comparison standards and monuments, the husbanding of resources to satisfy the needs of the world's population). Considerable emphasis is placed upon the successes achieved by the socialist countries in dealing with the problem of raising living standards while at the same time protecting the

environment, as well as on systems of integrated measures implemented in transforming landscapes and ecosystem complexes (establishment of forest protection zones, creation of irrigation systems, draining of marshy areas, crop replanting, creation of man-made bodies of water, preservation of species variety, etc.).

Increased attention in all phases of the course is being devoted to interrelations and interactions in the organic world. Considerable emphasis is placed on supraorganismic systems, with the influence of human activities on these biosystems and measures to protect them receiving thorough treatment. As early as in grade VI pupils learn about the links which exist between and among plants, animals, microorganisms and inanimate nature. Food chains receive special attention. What this amounts to is that pupils develop a sound grasp of the complex supraorganismic system known as biocoenosis, even though the term as such is neither mentioned nor defined.

Pupils' understanding of supraorganismic systems is enhanced in grade VII, where the natural community is defined by drawing upon a large body of material on plants and animals, on the variety of plant and animal species, on their place in food chains and their role in ecosystems, and on animals as an important factor in natural communities.

Knowledge concerning supraorganismic systems is further deepened and sytematized in the concluding units of grade X. Pupils at this level become acquainted with the structure and functions of a biocoenosis, with the ecological pyramid rule, and with the turnover of materials and energy flows which define the unity and stability of a given biosystem. The concept of an agrocoenosis as an artificial ecosystem, whose structure and functions are studied in comparison with a biocoenosis, is introduced at this stage. The role of agrocoenosis in the biotic turnover of substances and in human existence is studied. The concluding units of the grade X biology course are aimed at integrating the knowledge about ecology and nature protection measures mastered by the pupil throughout his previous studies.

The increased emphasis on ecology in the secondary-school biology course is reflected not only in the deeper and more purposeful presentation of environment-related topics in the final units of the biology course in grades VI, VII and X, but also in the treatment of other topics. For example, the study of the principal groups of plants involves consideration not only of the morphological-anatomical features and the national economic significance of the species studied, but also of the place and role of these species in living nature, their rational use , and their protection.

A similar approach is applied to the study of various animal species, while the familiarization of pupils with the functioning of the human organism makes it possible to demonstrate its dependence on the state and condition of the environment.

One technique used to render the ecological training of youngsters more effective consists in checking the results of summer assignments in botany. These entail the field observation of plants in various natural environments. Another one is to conduct ecological and nature protection discussions in connection with field trips, for example, field trips in grade VI include not only the study and observation of various flowering plants, but also of their habitats, with due note being taken of their adaptation to life in the context of a given plant community.

Thus, the step-by-step development of ecological notions in grade V through X and the familiarization of pupils with supraorganismic systems makes it possible to equip them with knowledge concerning the scientific principles of nature protection and with the use of these skills for the assessment of human activities and their impact upon nature, thus imbuing youngsters with the sence of how important it is to protect the natural environment. The ways used to develop caring attitudes to nature

include teaching pupils to refrain from culling plants and capturing animals for a personal herbarium or zoo and from conducting cruel experiments on animals in connection with lessons in anatomy, zoology, and human physiology and hygiene.

The presentation of ecological material in the biology textbooks follows the presentation of information concerning plant and animal biology, the principal taxons of the plant and animal world, human biology, and the general principles underlying all of living nature in the final year of the biology course.

The tasks of hygiene education as part of the present secondary-school biology course.

The streamlined Soviety secondary-school biology course places increased stress on the upbringing of young people in the spirit of Communism. This means emphasizing issues with ecological, hygienic, ideological-political, moral and other implications.

This increased emphasis on the education of young people in matters of hygiene is reflected in the fact that the curriculum calls for "the conduct of hygiene and sex education in an organic interrelationship with education in morality". The curriculum places particular emphasis on knowledge concerning the structure and functioning of organs and systems of organs as the basis of the rules of hygiene. This material is also used to bring to light the effects of physical stresses on the locomotive, cardiovascular, respiratory and nervous systems; to explain the rules of hygiene in relation to hygiene and to respiration, diet, skin care, sight, hearing, and physical and mental exercise; to make pupils aware of the ways of preventing infectious diseases and anaemia and of avoiding the harmful effects of smoking and alcohol misuse on the organism; to explain and justify pollution control measures.

The system of knowledge about biology is used most comprehensively and consistently as a scientific basis for hygiene lessons in grade VIII, i.e. as pupils learn about human anatomy, physiology and hygiene. At this level the youngsters become acquainted with the hygiene-related aspects of environment protection, studying the effects of chemical, physical and biological factors on the human organism and the changes which occur in these factors as a result of human activities. Particular attention is given to the effects of changes in environmental factors on the structure and functioning of the circulatory, respiratory, nervous and other systems.

Pupils' familiarity with the principles of hygiene as the science of preserving and improving one's health and with the factors which affect health makes them aware of the harmful effects of alcohol and smoking and the benefits of physical exercise in the development of the skeleton system and muscles and of good posture in preventing distortion of the spinal column. Having learned about the need for hygiene in both physical and mental activity (especially in learning), the youngsters are able to budget their study and leisure time in a more effective way.

Considerable stress is laid on the development of negative attitudes to harmful habits such as smoking and alcohol abuse. The deleterious effects of nicotine and alcohol on the functioning of the circulatory system, digestion, respiration, nervous activity and the development of the human organism in general are all thoroughly covered.

The biology course also includes topics in personal hygiene, sex education and preparation for family life.

The curriculum prescribes that the pupil must not only master a certain body of information, but also be able to explain the effects of physical work and sport on the organism, able to give the reasons for bad posture and flatfootedness, anaemia and intestinal worms. He must also be able to say why the body must be properly cared

for, why a proper balance must be struck between work and leisure, why good diet is necessary, and why smoking and drinking of alcohol are harmful. Finally, he must be able to give first aid in case of cuts, scrapes and bruises and know what to do to prevent and deal with sunstroke.

Information on hygiene and sex is offered to pupils not only by way of textbooks and other printed matter: there are also motion pictures, film strips and slides, and tables illustrating the action of beneficial and harmful factors, all of which are helpful in making the pupil maintain health and become stronger. Hygiene lessons provide an opportunity for explaining the policy of the Soviet government and presenting the plans and measures being implemented in the Soviet Union in order to maintain and improve the health of the people. This task is regarded as an important concern by the State, which the latter handles by offering free medical care and by maintaining and extending its broad network of clinics, hospitals, sanatoria, etc.

Augmenting the polytechnical orientation of secondary-school biology.

Our age of rapid progress in science and technology imposes increased demands on the preparation of young people for life and work in various fields of endeavour. This fact was one of the considerations allowed for in streamlining the secondary-school biology course and in enhancing its role in the polytechnical education and occupational guidance of young people. The biology curriculum has as its principal objectives, the shaping of broad polytechnical outlook and assistance to the young person in making an appropriate career choice through the explanation of biological laws and patterns and of the principles of operation of those branches of modern industry and agriculture which make use of biological systems. As pupils go about studying various forms of organization of living systems, considerable stress is laid upon instilling Communist attitudes to labour and upon the development of practical skills and attitudes.

The task of polytechnical education are presently being dealt with more succesfully because of the higher scientific level of the new biology course, which now reflects the scientific principles underlying agricultural production, the mocrobiological industry, genetic engineering and plant and animal breeding. Pupils now develop a clearer and better articulated grasp of ecology as the scientific basis of nature protection measures, and a deeper understanding of the anatomical-physiological principles of human work.

Secondary-school biology in the Soviet Union today embraces the whole of the system of biological knowledge which constitutes the scientific basis of production. The biological systems covered are as follows:

- the patterns and regularities of metabolism, growth, development and reproduction of organisms, together with their special features related to genetic makeup of individuals and to the habitat, as the scientific basis of agriculture and animal husbandry;

- the theory of the motive forces, directions and results of evolution together with the regularities of genetic inheritance and variability of organisms as the scientific basis for the creation of new forms;

- the theory of populations, species, biocoenoses, agrocoenoses and the biosphere; of the completeness and stability of these ecosystems and of their changes under the influence of the motive forces of evolution, and especially of human activities and interventions, as the theoretical basis for the creation of highly productive ecosystems; population and species control; the rational use of natural living systems; the maintenance of equilibrium in the biosphere and the preservation of a livable environment;

- theories of higher nervous activity, along with anatomy and physiology, as the scientific bases of human labour;

- the theory of the structure, vital activity and reproduction of microorganisms (fungi and mounds) as the scientific bases of the microbiological synthesis and production by the microbiological industry of feed proteins, antibiotics, enzymes, etc.

Pride of place in the system of polytechnical knowledge offered within the secondary-school biology course is accorded to the scientific bases of agricultural production whose successes are decisive in satisfying the food needs of the population and the demand of the meat-and-milk, textile, leather and other industries of raw materials.

The biology course for grades V and VI equips pupils with systematically presented knowledge concerning the structure and vital activities of plant organisms, their interrelations with their environment, and the dependence of vital activities, growth and development on ambient conditions. This knowledge helps them to understand what conditions are required for the successful cultivation of crop plants. They then became acquainted with the classification of flowering plants, with various families of crop plants, with the agrotechnology involved in their growing, and with methods of their propagation and yield improvement. Reliance in this context is placed upon general knowledge concerning the vital activities, growth, development and reproduction of plant organisms.

The familiarization of pupils in grade VII with the structure, vital activities, individual development and reproduction of various animals and with the historical development of the animal world helps them become aware of the practical significance of such knowledge for the growing of silkworks and silk production, for fish breeding in hatcheries and the maintenance of fish yields in natural water bodies, for poultry breeding and poultry meat production, and for the cattle, pig, sheep and horse breeding and raising industries.

The study of the structural features and vital activities of bacteria and fungi in grade VI and of cytology and the structural-functional organization of eucaryotes and procaryotes in grade X serves as a basis for understanding the technology of microbiological production and the advantages offered by the microbiological synthesis of organic substances over the growing of plants and animals in the production of feeds, agricultural plant and animal protection, and pest and disease control in forest areas.

Whereas pupils in grades VI and VII are simply acquainted with the achievements of Soviet breeders and with plant varieties and animal breeds developed in our country, grade X youngsters learn about the methods and approaches employed in breeding. Mastery by pupils in grades IX and X of the theory of evolution, hereditary patterns and variability help them to gain insight into the biological essence of breeding methods and into the role of this field of science in the development of agriculture and the microbiological industry, as well as in augmenting the productivity of plant cultivation and animal raising.

One of the objectives pursued in reworking the secondary-school biology course was that of placing greater emphasis on the scientific bases of agricultural production. Thus, pupils in grade V are now called upon to master not only theoretical information concerning the structure, vital activities, growth, development and reproduction of the plant organism and to learn about the technology of growing several types of crop plants, but also to carry out a series of practical exercises at special school areas set aside for the purpose. They are taught to set up experiments and to observe the growth and development of plants (e.g. the propagation of potatoes using eyes, sprouts and tips). Other activities include determining the effect of earthing on bulb development and potato yields; of stem pinching on cucumber-plant fruiting; of pruning on the yields and ripening rates of tomatoes and on the flowering rates and inflorescence of dahlias; of pinching the

main stem of decorative flower plants on the numbers of lateral shoots and flowering times; of the use of fertilizers on the growth, development and yields of crop plants; of the variation of plant feeding areas on various plant parameters.

More thorough study of crop plants and familiarization with modern techniques, used in their cultivation is made possible by the increased amount of time devoted to the study of flowering plant families and the possibility of replacing the one or two plant families suggested in the curriculum by other families whose species are most widespread and of considerable practical significance locally.

Grade VI biology likewise provide for a system of practical exercises on the growing of crop plants and the performance of experiments with such plants with the aim of determining optimal agrotechniques and means of increasing harvest yields. In the spring-summer period pupils carry out the following experiments and observations: the earthing of crop plants and its effect on their development and harvest yield; hardening of tomato seeds and seedlings to increase the resistance of the plant to cold spells; determining the most effective means of blackberry propagation; comparative study of crop plant varieties; acquisition of skills in growing the crop plants most important in the given region with the aid of advanced techniques, coupled with observation of their growth and development.

Pupils in grade VI also conduct observations and look after wild and domestic animals and study damage to plants caused by insects. By way of giving greater importance to the problems of animal husbandry (including poultry farming and cattle raising), the Grade VII biology course now includes units on "The class of birds" and "The class of mammals", which were incorporated into the course at the expense of topics in systematics. The teacher is asked to choose three out of five ecological groups (park, garden, meadow, field, and forest birds) in order to allow for local conditions. The number of mamalian orders to be studied has been reduced, as has the number of species studied within each order. The above changes in the curriculum does not reduce its scientific soundness: quite the contrary, they make it possible to centre attention on the basic issues and to devote more time to practical knowledge.

Pupils in grade VIII are called upon to master a system of knowledge concerning the anatomical-physiological features of the human organism and higher nervous activity. This enable them to appreciate the role of physical and mental effort and the need for proper balance between work and leisure in the development of the human organism and the maintenance of its health.

In grade IX the pupils concentrate on Darwin's theory of evolution and his teaching on heredity, variability and artificial selection as the mainsprings of the creation of new crop varieties, as well as on the theory of biological progress and regress, which enables pupils to understand why certain species become extinct while others flourish.

The problem of creating new crop varieties is dealt with more completely and profoundly in grade X, where the treatment of plant, animal and microorganism breeding involves the amalgamation of evolutionary theory with genetic patterns and regularities to highlight the achievements of plant selection and animal breeding.

The secondary-school biology course includes the concept of an agrocoenosis as an artificial ecosystem whose productivity depends entirely on the agrotechnology of crop plant cultivation and on the effectiveness of disease and pest control measures. The latter are, of course, based on theoretical knowledge concerning the structure and vital activities of plants and their interrelations with their habitat (biotic and abiotic factors).

All five years of the biology course also serves as a means of conveying knowledge about the scientific principles of nature protection. Understanding of plant and animal organisms and their interactions with the environment makes it possible for pupils to discover for themselves the need to protect plants and animals, to respect their essential unity. The development of the notion of a species and later of a population, the variety of species, the relative scarcity or abundance of its representatives, and their occurrence in the world enables pupils to become convinced of the need to regulate the number of individuals in each species and to maintain populations at appropriate levels to prevent extinction and to conserve life on our planet which; once it is diminished by the loss of a species, can never be restored to it former richness. The mastery of pupils of information concerning biocoenoses serves as a basis for explaining the need to protect this ecosystem, such protection being a prerequisite for the preservation of species and a natural environment whose balance can be properly maintained.

The polytechnical orientation of secondary-school biology has been enhanced by emphasizing knowledge concerning the scientific bases of production within the terms of the "Basic requirements" section of the curriculum. Thus it is pointed out in the requirements as to the knowledge to be mastered by pupils in grades V, VI and VII that pupils must learn to make practical use of what they learn about botany by growing plants, to find out about the need to protect and make rational use of plants, to appreciate the place of animals studied in nature and the role of such animals in the human economy. Grade VIII pupils must know about the effects of physical stress on the support-locomotive, cardiovascular, respiratory and nervous systems and the significance of mental and physical labour in human existence.

Ninth-graders are called upon to learn that plant varieties and animal species have been created by man using the tools of artificial selection. On entering grade X pupils begin to gain a sound grasp of the method used in breeding plants, animal and microorganisms, learning about the achievements of breeders in the past. They study the positive and negative effects of human activity on the biocoenosis and the biosphere and the hereditary patterns on which nature protection measures are based. They also become familiar with the techniques of growing and developing new plant and animal varieties.

The problems of polytechnical education are now being dealt with more successfully by using visual aids to explain the use of biological patterns in practical activities. These include motion picture films such as "The Vegetative Reproduction of Plants", "The Biological Method of Insect Pest Control"; "Breeding Methods in Animal Husbandry", "Plant Breeding", etc. The practical significance of theoretical knowledge is illustrated in a variety of filmstrips bearing titles such as "Animal Keeping and the Fur Industry" "Animal Restocking", "Protecting Air and Water", "Soil Protection", "Protection of the Environment", "Genetics in Animal Husbandry", "Plant Breeding", etc.

An important role in the implementation of the polytechnical approach is played by biology textbooks which contain a systematic presentation of polytechnical information. For example, the botany textbook demonstrates on an elementary level the way in which knowledge of plant biology is used in plant growing. Another example: the study of flowering plant families covers not only the biological characteristics of various species, but also the biology of crop plant vaieties which has to be allowed for in their cultivation.

The zoology textbook explains the significance of animals in nature and in human life and economy activity. For example; it contains a detailed discussion of the role of earthworms in the treatment of soil with humus and in soil loosening to ensure that the roots have access to moisture and air. The description of the role of insect pests by insect predators, etc.) is complemented by a presentation of the role of insects as a whole. Similarly the treatment of birds in nature is not limited to a discussion of the role of birds in nature and their significance as far as man is concerned: special consideration is also given to the poultry industry (the importance of poultry farming, poultry varieties, and industrial poultry production).

4.6. The shaping of a dialectical-materialistic world outlook in pupils through the study of biology.

The streamlining of Soviet secondary-school biology was from the start directed at laying greater emphasis upon the development of a scientific world outlook on the part of pupils. The list of educational objectives points out the need for developing a dialectical-materialistic and atheistic world outlook in pupils. The importance of this task is supported by the list of knowledge and skills that pupils are required to master. For example, pupils in grade VI are required to develop the ability to draw conclusions concerning the historical development of the plant world and the untenable character of religious explanations of the origin of planets. This means that in the course of studying the principal plant groups the pupil is asked to make systematic comparisons between a higher group with the one below it, noting similarities in order to make him see that higher forms develop out of less highly organized ones and that the increasing complication of life forms testifies to the validity of evolutionary theory.

Pupils in grade VII are required to draw conclusions about the development of the animal world and to understand the notion that it is constantly changing. This means that in the study of each new systematic group (type, class) comparisons must be made between animals belonging to different taxons. This enables pupils to recognize the signs of increasing complication and thus appreciate the progressive character of evolution from less organized to more highly organized life forms. Teaching seventh-graders Darwin's theory of evolution on an elementary level makes it possible to explain the natural-scientific causes of phylogenetic links and to refute the notion of the divine origin of plant and animals.

Grade VIII pupils are required to be able to present the proof of man's descent from the animals. This entails comparing the organ systems of man and the animals, identifying the signs of complication, and drawing conclusions about the increasing complexity of the organic world.

The aspect of the course richest in philosphical material is that of biology in general. The curriculum specifies that pupils must be able "to apply Darwin's theory in explaining the process whereby adaptations araise, describing the way in which new plant varieties and animal breeds are developed, and criticizing religious-idealistic views concerning the origin of species and the adaptation of organisms, using Engels' theory of labour to refute antiscientific views as to the origin of man".*

The requirements also apply to pupils in grade IX. They become even more rigorous in grade X, where pupils are required to employ the entire system of biological knowledge to prove the material and dialectical character of biological processes and to criticize religious-idealistic notions concerning the origin and essential nature of life.

The streamlined curriculum requires that the biology teacher stress the principal biological theories and patterns which the pupils must not only master but also use for setting out dialectical-materialistic explanations of the phenomena of living nature. In other words, they must be able to prove the role of genes in the formation of features; to determine the causes of mutations in disturbing the process of DNA molecule doubling, RNA and protein synthesis, cell division, etc.

*Programma vos'miletnei i srednei shkoly. Biologiya (Curriculum of the Eight-Year and Secondary School. Biology). Moscow, Prosveshchenie, 1982, p. 38

The study of biology equips pupils with knowledge concerning the structure, functioning and development of living sytems. It is helpful in the integration of this knowledge into the pupil's view of reality, thus exercising a positive effect on his attitudes concerning the surrounding world. Shaping a scientific world outlook means devoting maximum attention to the philosophical implications of scientific knowledge. Moreover, pupils must be trained in the use of these implications, which they gradually become their personally held views and convictions. It is important in this connection to elucidate scientific facts, phenomena and processes in the light of the biological theories and regularities constituting the system of philosophy-shaping knowledge, so that the latter may be seen as provable and proven.

The biology course offered in grades V - X provides for a step-by-step exposition of biological concepts, but it is largely in grades IX and X that pupils are confronted with the biological theories and regularities which enable them to generalize and systematize knowledge concerning the structure, functions and development of biological systems in conformity with the appropriate tenets of dialectical-materialistic philosophy at a fairly sophisticated level of philosophical abstraction.

A series of methodological guidelines helpful in shaping the pupil's world view have been set out by I.D. Zverev.* They comprise:

- thorough philosophical justification by the teacher of the entire system of fundamental biological ideas, theories and concepts (this is the key to the purposeful buildup of the natural scientific basis of the pupil's eventual world view);

- the step-by-step definition and assessment of each step of the educational process from the standpoint of its role and its contribution to the process of forming a scientific world outlook among pupils;

- the alignment of biology-related philosophical issues with the subject matter of other school courses establishment of "intersubject links";

- the justification and proof of conclusions and generalizations of general biology, and links already established between theory and practice;

- activation of learning on the part of pupils to ensure comprehension of basic ideas (effective techniques include various types of independent creative work, the setting up of problem-solving situations with elements of research, and the performance of learning tasks involving creativity);

- the systematic assessment of the degree and quality of understanding of philosophical issues by pupils, coupled with discussions concerning pupils' attitudes to their recently acquired knowledge of nature;

- the motivation of pupils to apply their general knowledge of biology to learning and practical activities (these in turn throw light on pupils' attitudes to reality, their views, the steadfastness of their convictions, and the correctness and propriety of their actions and behaviour).

*Zverev, I.D. (ed.), Problemy metodiki obucheniya biologii v srednei shkole (Problems of Biology Instruction in the Secondary School). Moscow, Pedagogika, 1978, pp. 175 - 176

The process of shaping a scientific world outlook in pupils is not simply a matter of their taking up ready-made philosophical positions: it requires that each pupil take up his or her own stand, his or her own attitude towards the real world. Assessing the degree of dialectical-materialitic insight of pupils is easier through questions nd special situations that encourge pupils to present their own views concerning nature and to defend their opinions.

Much attention in Soviet schols is devoted to the task of bringing up pupils in a spirit of atheism. The success of this enterprise depends on the depth with which they grasp the system of scientific concepts which constitutes the basis of the dialectical-materialistic world outlook. The transformation of these concepts into the pupil's own views and convictions helps to root out antiscientific religious notions.

I.D Zverev mentions the following principal categories of scientific-atheitic thinking*

- scientific proofs and theories explaining the natural-histrical origins of the plant and animal worlds, man's descent from the animals, and the untenable character of religious notions about the creation of plants, animals and man by "God";

- the materialistic understanding of living nature coupled with the exposure of religious claims concerning the divine mystery" and unknowability of the world;

- the natural-scientific explanation of interrelations in nature, of the causes of adaptation, and of the nonsensical character of religious divagations concerning "divine harmony" and absolute purpose;

-- physiological data concerning human brain activity and the manifestation of higher brain functions that refute religious notions of the divine nature of "soul", its immortality and its separatness from the body;

- the foundations of the scientific approach to human health and the criticism of religious rites and customs which endanger health;

- the modern natural-scientific and socio-economic principles underlying man's interaction with nature and the senselessnes of religiously motivated attitudes to that interaction.

One of the approaches implemented in modernizing the Soviet secondary-school biology course consisted in placing increased emphasis on the dialectical-materialistic and atheistic education of young people. The streamlined biology curriculum fully reflects this approach. The new methodology incorporates a sharp critique of the so-called "areligious" approach to upbringing, i.e. of the replacement of a steadfast atheistic stance by the simple transmission of knowledge. It is pointed out that religious teachings themselves are being modernized, that there is a recrudescence of cult practices and rituals, and of various religiously-inspired social and ethical doctrines. All of which means that today the social nature of religion and its illusionary notions of man and the world ramain essentially unchanged. That is why it is so important to convince pupils of the groundlessnes, scientifically speaking, of religion in any of its guises, and to counter religious-idealistic notions concerning living nature with established theories and regularities, demonstrating the truth of natural-scientific interpretations in each and every instance.

*Zverev, I.D. (ed;), Problemy metodiki obucheniya biologii v srednei shkol (Problems of Biology Instruction in the Secondary School). Moscow, Pedagogika, 1978, pp. 153-154

The intellectual development of pupils through the study of biology

The steamlined secondary-school biology course is characterized by increased attention to the developmental function of education and the establishment of organic links between education and upbringing. The curriculum sets as an objective the development of logical thinking on the part of pupils, i.e. of their ability to analyze, synthesize and compare biological objects, to identify cause-and-effect relationships in biological processes, and to draw conclusions and make generalizations. Other requirements include the ability to recount what one has learned in one's own words using the appropriate scientific terms.

If this problem is dealt with successfully, it means that the pupil will learn to think logically and make effective use of logical operations as he goes about his studies. The curriculum requirements concerning knowledge to be acquired by pupils in Grade V specify that the youngsters must be able to identify the parts of a cell, tissues, organs, types of roots and root systems, leaves, fruit, flowers and the part of a seed, sprouted seed and flower. This means fifth-grades must be able to analyze and synthesize biological objects. They are also required to establish links between the structure and functions of cells and organs, to grasp the dependence of seed sprouting and shoot development on ambient conditions, to detect similarities and differences between various types of root systems, fruit and leaves, and to use their knowledge of botany in plant-growing exercises.

The intellectual sights for pupils in grade VI are set somewhat higher. At this stage youngsters must be able to isolate basic signs and features of a large variety of plants and classes. They are then called upon to use these signs and features to determine the systematic position of the species under investigation, i.e. mastering the operation of classifying the objects under study. The sixth-graders must be able to compare and give names to the principal features of increasing complexity in the structure of algae, ferns and angiosperms, a matter of great importance for establishing phylogenetic links between major taxons and determining their evolution in the direction of increasing complexity. As early as in grade VI pupils must be able to identify the features of adaptedness of a given species to life within a given plant community, which means that they must be able to analyze (identify features), synthesize and perceive cause-and-effect links. They must also be able to draw conclusions concerning the development of the plant world and to demonstrate the untenability of religious views concerning the origin of plants. This is a fairly comple mental operation, but one which the pupil must nevertheless master, and one which is fully within his grasp provided his attention is systematically drawn to plant species belonging to various taxons characterized by differing levels of organization.

The mental activity required of pupils in grade VII is still more demanding: pupils at this level must be able to carry over their intellectual skills from botanical objects to those of zoology. The biology curriculum requires that seventh-graders learn to use tables, drawings, collections and preserved (wet) specimens to identify animal (fish and mammal) organs and organ systems, to compare systems of organs of various vertebrate classes, and to draw conclusions concerning the historical development of the animal world while at the same time refuting claims about its alleged immutability.

Studies in grade VIII entail the transfer of pupils' intellectual abilities onto a different biological object, namely man. The youngsters are now required to be able to identify organs and organ systems, to explain the connections between their structure and functions, to distinguish between arteries, veins and capillary vessels, and to show how unsupported are the views of man's origin offered by religion.

The most complex intellectual skills demanded within the secondary-school biology course are developed in grades IX and X within the context of general biology studies. Whereas pupils in grades V - VIII are asked to think analytically and synthetically about biological objects, those in the senior grades are called upon to analyze processes, phenomena, and the basic propositions of biological theory. Another requirement is the ability to analyze and compare the views of various scientists and schools of thought. Thus, pupils in grade IX must be able to distinguish between the various components of the motive forces of evolution, the stages of human evolution, the basic aromorphoses and idioadaptations, and biological progress and regress in the evolution of plant and animals. They must also learn to identify cause-and-effect links between the motive forces of evolution, its results and its directions, as well as to compare closely-related species, natural and artificial selection and various anomorphoses. Finally, they must be able to apply Darwin's theory to the scientific-materialistic explanation of historical changes in living nature and Engels' teaching in explaining the causal factors underlying man's origin.

The mental skills demanded of tenth-graders are no less sophisticated. At this level the pupil must be able to identify the various components of cells, populations, biocoenoses and the biosphere, as well as to compare plant and animals; mitosis and meiosos, various types of cross breeding, and initial forms with offspring generations. Tenth-graders must also be able to use their knowledge to prove the dialectical and materialistic character of biological process, to criticize religious idealistic views concerning the origin and essential nature of life, and to explain nature protection measures and methods employed in the development of plant varieties and animal breeds.

Pupils' ability to master the range of intellectual, philosophical and practical skills described above constitutes convincing evidence of the fact that biology really does serve to develop pupils' mental faculties.

As was shown by E.P. Brunovt and E.T. Brovkina,* the acquisition by pupils of various mental skills facilitates the assimilation of knowledge about the objects and phenomena of living nature and about biological patterns and regularities. It enables pupils to consider phenomena in various aspect, to establish various links, and to identify common features in objects or processes belonging to a given group. All of this means that youngsters who have mastered the required battery of mental operations are better able to assimilate knowledge, something which is certainly of value in shaping a scientific outlook on the world.

The intellectual training administered to pupils in the course of biology studies involves the use of special devices and techniques appropriate to the subject matter. The effectiveness of the following sequential approach to the study of the structure and functioning of biological systems has been proved effective by experiment: primary synthesis (where the significance of an organ or other object is explained in the most general terms); the analysis of the details of structure and function; generalizing synthesis (complete description of the significance of a given organ on the basis of the established interrelationships between its parts) incorporating a high degree of specificity. This approach makes it possible to train pupils in analytical-synthetic thinking while at the same time giving them a sound grasp of the structure and functions of cells, organs, organ systems and organisms.

* Brunovt, E.P. and Brovkina, E.T., Formirovanie priemov umstvennoi deyatel'nosti pri obuchenii biologii (The Shaping of Mental Skills Through the Study of Biology). Moscow, Pedagogika, 1981.

Research has shown that in training pupils to perform primary synthesis one must see to it that they be able to identify the most salient features of the entity as a whole, to place the object in question within a system, and to establish where a given phenomenon belongs within a group of similar processes.

Training in analysis fosters and facilitates the correct identification of the parts of a whole, the establishment of links of subordination between these parts, and the determination of the principal aspects (facets, features) which reflect the essential nature of the object. It is highly important in this connection to make a proper choice of biological objects whose salient features pupils may be may be readily identified by the pupil. Training in analytical thinking likewise helps pupils to become accustomed to describing biological objects as precisely and as comprehensively as possible. This requires that pupils be trained in the art and science of observation. In other words, they must be taught to identify salient features and to describe them correctly.

Training in synthetic thinking permits youngsters to perceive the wholeness of biological sytems, as well as to establish links both within and between systems (within the cell and between cells; between tissues, organs, organisms, populations and biocoenoses). Such training begins early, with pupils being asked to consider the structure of an organ in connection with its functions in the context of practical exercises, field observations and routine classroom experiments. It is bolstered by implementing the problem-solving approach and by the proper organization of learning activities. Ways and means of ensuring that pupils grasp interrelationships between biological systems include the use of graph-type learning schedules and adherence to a prearranged sequence of learning stages and operations, e.g. the definition of the significance of an ecosystem; the identification of principal components and their relative subordination; the description of the principal components of an ecosystem; the description of the structural features of each component and its functions; the establishment of the links between the parts of an ecosystem taken as a whole. The demonstrable ability of pupils to express the links between the components of a system schematically provides a measure of their ability to think abstractly. It is also an indication of a high level of mental development in general.

An important indicator of the level of pupils' mental development is the ability to make comparisons. In order to become skilled in this activity youngsters must be trained to adhere to a certain sequence of operations, i.e. naming the object; identifying the salient features of objects being compared; actual comparison through the identification of similarities and differences; drawing conclusions. The most effective way to proceed with such training is to begin with very similar objects and then go on to increasingly dissimilar ones while highlighting a small number of features. What pupils essentially rely on in the course of comparisons are such operations as analysis and synthesis, generalization and abstraction. As youngsters gradually become skilled in comparing biological objects, processes, phenomena, views and theories, they likewise gain increasing insight into biology as such.

Pupils automatically become skilled at establishing cause-and-effect relationships as they go about studying the various concepts of physiology. Such topics as the species variety and species adaptation to environment are dealt with as consequences of the historical development of the organic world, a development in turn impelled by the motive forces of evolution. In considering any biological phenomenon one must draw pupils' attention to its underlying causes. Pupils in grades V - VII are as yet unfamiliar with the theory of evolution, becoming acquainted with its fundamental propositions only in connection with the concluding unit in grade VII, and in cursory fashion at that. But the natural and objective character of biological phenomena must be stressed even prior to exposure to Darwin's theory. In other words, pupils can be trained to make statements such as "the variety of species arose in the course of historical development", even though the causes for

development are not made explicit. On the other hand, the causes of evolution are dealt with in considerable detail in grade VIII and especially in grade IX.

One of the principal objectives of the biology coure is to ensure the gradual buildup of general biological concepts from to year. Coping with this task means applying a carefully graduated system of generalizations: particular concepts must be formulated on the basis of generalized facts and then shaped into definitions. This is followed by the generalization of a number of particular concepts into a concept which is more general. Each step in the concept-formation processes is completed by its extension and deepening on the basis of knowledge already acquired by pupils.

Analaysis of school experience shows that pupils cannot become skilled in generalization through independent effort: they must be encouraged to generalize facts and to transform specific concepts into more general ones. This calls for special training. This consists in first teaching pupil to analyze facts, and then to construct definitions, to formulate conclusions, to identify common features in objects and phenomena, and to recognize particular phenomena as belonging to a broader class.

The ability to generalize requires a certain amount of skill in abstract thinking, which means that mental exercises involving generalizations are a means of cultivating logical thinking in general. Training in generalization and abstraction in turn helps pupils to become increasingly skilled at drawing conclusions. Incremental increases in the amount or volume of material to be generalized (an item within a section, a section, a unit with several sections) and gradual transition from particular conclusions and phenomena to conceptual generalities help to develop the skills of generalizing and thinking in abstract terms.

Pupils experience great difficulty in developing the ability to fit a particular phenomenon within a more general concept, law or theory in biology. Once this skill is acquired, however, it enables the pupil to take a meaningful stance in regard to any fact, and to assign to it its proper place in the system of knowledge already mastered. Its acquisition within the biology course means learning to detect common features and regularities on the level of facts, processes and objects (the universality of the characteristics of living things: variability, genetic inheritance, adaptedness, interrelationship between structure and function, etc.). Highly important in this connection is the early introduction into the biology course of what we have been calling "biological patterns and regularities". This makes it possible to class specific phenomena as representing more general patterns, which in turn facilitates the assimilation of factual knowledge in clearly structured form.

Classroom practice shows that there exists a type of purely formal knowledge whereby pupils are able to state definitions in the correct way but cannot apply them to specific circumstances. This can be attributed to the fact that they do not possess the intellectual skills necessary for the concretization ("fleshing out") of general concepts. Imparting these skills means that the teacher must: a) keep asking that the pupil provide his own examples to illustrate a particular pattern or regularity; b) insist on the recognition of the fact that a general regularity subsumes something of a more specific nature; c) require that a given biological object be described in terms of the appropriate general concept or concepts.

Dealing with the problem of training pupils to generalize and to concretize ("flesh out") general concepts is made easier by systematic instruction and by the structuring of pupil knowledge into a system. The systems approach to knowledge and knowledge acquisition is implemented as a hierarchical system of interlocking general and particular concepts. It is very important in the process of instruction to point out the subordination of concepts within the overall hierarchy, i.e; to indicate that which is general on the one hand and that which is particular on the other. The systematization of the knowledge being acquired by pupils is made easier by the comparison of diagrams and tables by the pupils themselves, by the statement of

general conclusions to be retained within each leson and study unit, and by the highlighting of key concepts in clear subordination to one anther. For example, in studying a leaf as part of the botany course, pupils learn about its morphology and anatomy, its position along the stalk, the structural features of the leaf blade, the differing leaf shapes of various palant, and the distinctive features of plants which grow in various climates. The main components of this multifaceted system of knowledge are the concepts of photosynthesis and water evaportion via the leaf on the one hand and the internal and external structure of the leaf in connection with these very important functions on the other. This is why concepts introduced for the first time within each topic and each lesson must be fitted into a general system of basic knowledge concerning photosynthesis and water evaporation, together with the adaptedness of plants to the carrying out of these functions.

One important indicator of pupils' mental development is their ability to make use of newly acquired knowledge in various unfamiliar circumstances, i.e. to carry over their knowledge and apply it to new situations. The command of this skill is a measure of the depth of acquired knowledge and of the pupil's level of awareness of it. In other words, it provides an indication of the degree of mental sophistication attained by the youngster. Training in the deployment of reasoned argument and in the application of knowledge to new situations helps pupils to cope with learning problems calling for both practical and intellectual agility. Problem-solving situations are used extensively in the study of concepts in cytolgy and genetics as a means of making learning more effective. Their use in connection with other biological concepts is also increasing. Biology pupils seem to be particularly responsive to problems of a polytechnical character, i.e. to situations involving issues of environment and hygiene. The ability of the pupil to deal with such problems is a reliable yardstick of his or her mental development.

Another important indicator of development is the mastery of not only intellectual but also practical and general educational skills. The streamlined biology curriculum sets out criteria whereby one can assess pupil ability in conducting observations and carrying out experiments. Criteria for assessing experimental ability includes the proper definition of the purpose of an experiment, the independent choice of objects and apparatus, adherence to the required sequence of operations in carrying out the experiment, and the scientifically sound, logical description of observations and interpretation of experimental findings.

The readiness of pupils to conduct observations is evidenced by correct statement of the purpose of observation,the identification of the salient features of the object under investigation, and the formulation of the appropriate conclusions. It is highly important that in carrying out experiments and observations pupils not only describe the outer manifestations of living nature, but also indicate their essential significance. In other words, thinking in terms of pictures and images (visualization) must become the basis of logical, abstract thought.

A considerable role in the development of pupil knowledge is played by general skills such as the use of textbooks and other study materials. The streamlined biology curriculum prescribes training in the use of textbooks and various types of reference works, in summarizing the contents of parts of a section or an entire section, in working with drawings and diagrams, in finding answers to questions in their textboooks, in outlining the contents of an article or text unit, and in using textbooks to study various course issues independently.

Systematic work with the aid of a textbook enables pupils to locate quickly the information required in a text, to extract additional information from figures, to pay attention to that which is most important and to draw conclusions. These skills are developed gradually, on the basis of exercises which grow increasingly complicated from year to year. Whereas pupil assignments in grades V - VII involve such tasks as outlining an article; retelling the contents of a passage in one's own words and locating a text passage which corresponds to a given figure, those in the higher

grades call for outlining, amplifying definitions and concepts, summarizing, drawing of scientific-materialistic conclusions, establishing of cause-and-effect relationships, and adducing proofs which demonstrate the material unity of living nature.

Most information is contained in the descriptive and narrative portion of a given textbook. Assignments are formulated in accordance with the character of the text. The descriptive presentation of study material calls for establishing sequences of events (stages of special formation, phases of development of plants and animals, the stages of the historical development of the organic world and of man's origin), the identification of basic axioms (e.g. of the theory of evolution, of cell theory, and of the theory of the origin of life), the specification of the hierarchical order of particular and general concepts, and the exposition of the logic of a given phenomenon.

The explanatory character of textbook material calls for assignments involving the statement of the essence of biological phenomena, the establishment of interrelations and cause-and-effect relationships, and the explanation of phenomena by drawing upon fundamental theories and regularities (such as explaining the essential nature of photosynthesis and respiration, mitosis, meiosis and fertilization; describing the relationship between structure and function, organism and environment; elucidating the origin of adaptations, species formation, aromorphoses and idioadaptations with the aid of evolutionary theory, etc.)

Descriptive passages in a textbook are often followed by an explanation of the essential nature of the relevant biological phenomena and their causes. Assignments associated with such sections are of a joint character, involving both the establishment of the sequence in which biological proceses transpire (the stages of mitosis, embryogenesis, energy transfer and protein biosynthesis) and the statement of their essential nature (the material bases of genetic inheritance and variability, interrelationships within a biocoenosis, phylogenetic links).

Secondary-school biology textbooks consist largely of sections of the mixed type. For example, the description of biological phenomena (variability, genetic inheritance, the struggle for survival, natural selection, adaptation, species formation, cell metabolism, patterns of genetic transmission of characteristics, species composition of various biocoenoses biomass, and the boundaries of the biosphere) in the general biology textbook is followed by the presentation of their essence (the material essence of genetic inheritance and variability, the causative factors behind the struggle for survival and their role in evolution, the results of natural and artificial selection, the motive forces underlying the evolution of the organic world in general and anthropogenesis in particular, the biological significance of cell division and fertilization, photosynthesis and energy transfer, interrelations within food chains) or else by a discussion of the ways in which biological regularities are employed in the national economy.

Particularly important for the mental development of the pupil are assignments which involve the construction and compilation of graphs and tables in the process of working with textbook material. This involves the systematization of facts, the establishment of hierarchical links between concepts, and the collapsing of facts into a general statement. For example, in working with a text section concerning the historical development of the plant and animal world pupil are asked to construct a chart indicating the principal ages and periods along with the corresponding changes which occurred in the world's flora and fauna within the designated periods.

The mental activities required of pupils in working with drawings containing a certain amount of study material designed to facilitate assimilation of the subject matter and give specific meaning to the text are of fairly complex character. The simplest type of exercise of this category involves work with drawings which illustrate the stucture of biological objects: the pupils study the drawing and work up an account of the structure of the given plant or animal organism. Much more mental effort is involved when pupils are called upon to establish links between structure and function on the basis of a drawing (they may be asked, for example, to consider a drawing which shows the structure of a mitochondrion and then to establish the connection between the structure and functions of this organoid). Work with other drawings is directed at rendering biological phenomena and patterns more specific and understandable. For example, pupils may be asked to consider several drawings, compare them, and derive a general pattern or regularity. One illustration of this is an assignment in which pupils are required to examine drawings showing several individuals of the same species, and then to identify their similarities and differences with the aim of arriving at conclusions concerning the genetic characteristics and variability of organisms. Work with series of drawings facilitates the description of a given biological object and its environment and the identification of ecological connections. For example, pupils studying the adaptation of organisms are asked to examine text drawings carefully and then to write a brief description of the habitat of the objects shown, pointing out the signs of adaptation of the species shown to live in the given environment.

Having pupils work with drawings fosters the integration of logical thinking on the one hand and visualization on the other, with the final objective of developing the skill of shaping abstract concepts. The use of drawings in various phases of instruction (in broaching new material, in its review, in the course of checking assignments, and as an adjunct to textual material in the execution of homework assignments) ensures the development of a high level of skill in handling information presented in graphic form. The acquisition by pupils of the ability of working with books through appropriate practice both in and out of the classroom serves to increase their learning potential. This has a definite positive effect on the level of knowledge eventually attained. It is also helpful in normalizing the pupil workload.

The present article has been an account of the basic orientations of the recently modernized Soviet Secondary-school courses in biology, with some indications as to prospects for its further development.

4.7. ANNEX IV

ANNOTATED BIBLIOGRAPHY

BIOLOGY
Literature for the teacher and the pupil

Coping successfully with the tasks of biology teaching and study means drawing upon a wide range of methodological aids for the teacher and textbooks and other materials for use by the pupil. The selection of methodological aids available to the teacher includes general subject methodologies, lesson-by-lesson guides, and various publications concerning independent and out-of-class activities, classroom and laboratory equipment, nature protection work in and by the school, and practical field experimental assignments for pupils on the school plot. The pupil himself has available to him a wide range of anthologies and readers on every biological subject.

Taking the zoology and general biology segments of the overall biology course as examples, let us examine just what this range of methodological and study materials consists of (similar selections are available for all aspects of biology).

The principal guide for the zoology teacher is the book entitled Metodika obucheniya zoologii (The Methodology of Zoology Teaching) compiled by the leading Soviet methodologists V.F. Shalaav, E.T. Brovkina, A.I. Nikishov, B.V. Bogorad and E.V. Seredenko. Published by "Prosveshchenie", the work is already in its second edition. It consists of two parts. Part I is entitled "General aspects of zoology teaching" and Part II "Methods for dealing with particular topics". The first part sets out the theoretical principles of teaching zoology, namely content, teaching and upbringing methods, and forms of organization of the teaching-and-learning process. This is the basis for the specific methods used to present all topics within the course.

A considerable portion of the book is devoted to the methods of presenting individual topics. The most difficult issues within each topic are pointed out, methods for developing the leading concepts are outlined, and sample methodological recommendations for individual lessons are given. Emphasis is placed on methods of presenting the most complicated concepts which are of great importance for the upbringing and development of pupils while at the same time constituting the necessary basis for enabling them to grasp subsequent subject matter.

A work which beginning teachers find helpful is entitled Uroki zoologii (Lessons in Zoology) (by E.T. Brovkina and N.I. Kaz'mia, Prosveshchenie, 1981). This contains methodological recommendations concerning particular lessons. The book consists of an introduction and methodological recommendations indicate the basic notions to be conveyed in connection with the given topic, discuss their role in shaping the pupil's world view, as well as their place in the implementation of the polytechnical principle, in the development of learning activity, and in the shaping of intellectual and practical skills. Considerable space is given to appropriate methods for use in connection with specific lessons. Various options for presenting a given lesson are suggested. These permit the teacher to take into account such considerations as the teaching resources available.

The teacher requiring help in organizing independent activities can rely on Samostoyatel'nye raboty uchashchikhsya po zoologii (Independent Pupil Work in Zoology) (by L. A. Lutskaya and A.I. Nikishov, Prosveshchenie, 1977). The main section of the book is a description of independent activities, accompanied by appropriate exercises and assignments pertaining to the study of all taxonomic groups.

It is recommended that independent work be made to involve the use of various sources of knowledge actual natural objects, tables, textbooks drawings, etc). The assignments orient the pupil towards the application of the evolutionary approach and the study of the distinctive anatomical-morphological feature of animals belonging to various taxons from the standpoint of their historical development. Many of the asssignments have as their purpose the shaping of the pupil's views concerning the unity of the animal world and its origins in historical development.

Pupils have available to them the book Khrestomatiya po zoologii (A Zoology Anthology) (compiled by S.A. Molis, Prosveshchenie, 1971) and Kniga dlya chteniya po zoologii (A Zoology Reader) (same editor, Prosveshchenie, 1981). The latter collection uses simple language to tell about the structure, habitat, behaviour, place in nature, and importance in the national economy of the animals belonging to various systematic groups studied in the school zoology course. The book also contains interesting information about the life of animals and demonstrates the variety of species. This makes the collection suitable for use both in connection with lessons and in out-of-class work (for example in young zoologists' circles)

In a special section entitled "Check your conclusions by observing and experimenting" the book gives field observation assignments suitable for young people. Interesting information is also to be found in the sections entitled "Do you know that.....?, "Please note down", "that's very interesting!" etc. Facts about the life and work of major Russian and Soviet zoologists are included.

The list of publications for teacher and pupil in the field of general biology is no less extensive. The basic methodological guide is the book entitled Metodika obucheniya obshchei biologii (The Methodology of Teaching General Biology) (by the methodologists A.N. Myagkova and B.D. Komissarov), which is now in its second edition (the first edition appeared in 1973, the second in 1979). This guide is intended for grade IX and X biology teachers. It consists of two parts. The first part concerns the scientific and theoretical issues underlying the methods of teaching general biology, the purposes of such teaching, the content and structure of the course, the objectives and methods of educating young people in the spirit of Communism, and teaching methods as such (especially those which make it possible to orient pupil activity towards research), and forms of organizing learning activities. The second part concerns the methods of dealing with specific topics. Here the reader will find a justification of the place of each topic within the course, indications concerning its links with preceding and subsequent topics, a statement of the principal ideas (with an explanation of why these are important in the upbringing and development of the pupil), an outline of the principal ways in which studies can be organized, and a detailed discussion of methods of presenting particular lessons.

The teacher faced with the task of coping with the complicated final course in biology will find much-needed assistance in the lesson-by-lesson methodological guide entitled Uroki obshchei biologii (Lessons in General Biology) (by V.M. Korsunskaya, N.M. Verzilin, G.N. Mironenko and Z.A. Mokeeva, Prosveshchenie, 1977). This book contains a brief exposition of the theoretical issues involved in the teaching of the course and detailed treatment of methods to be followed in presenting lessons in grades IX and X. The methodology for each lesson begins with a lesson outline which briefly states the contents of the lesson, offers possible methods of presentation, and lists available literature sources. This is followed by a detailed discussion of the lesson, questions to test pupils' grasp of the subject matter, and comments on the organization of the pupils' learning activities.

The book contains an appendix with assignments which pupils can carry out on the school experimental plot. These assignments are intended to give real meaning to the complex theoretical isues covered in the classroom with a view to the pupils gaining a deeper and more secure grasp of the relevant subject matter.

A matter of great importance in the methodology of biology teaching is that of enhancing the independence of pupils as they proceed with their studies. This is precisely the purpose of the book entitled Zadachi i uprazhneniya po obshchei biologii (Problems and Exercises in General Biology) (by G.M. Murtazin, Posveshchenie, 1981) and Samostoyatel'nye raboty uchashchikhsya po obshchei biologii (Independent Work for Pupils Studying General Biology) (by I. P. Anastasova, Prosveshchenie, 1978).

The former work contains exercises involving the reproduction of learned material, problem solving and research (production of new information prevailing over simple reproduction of memorized material in the latter instance).

The assignments take the form of computational and experimental tasks, exercises, questions, work with diagrams, tables which the pupil is asked to fill in after comparing the specified objects, observations, and practical activites. Detailed solutions of typical problems are presented. The assignments in each section are broken down into three groups of increasing difficulty, "basic", "supplementary" and "difficult". The basic asignments are intended as front-of-classroom work involving all of the pupils, while the supplementary and difficult exercises are intended for youngsters with a special interest in biology.

The book is thus intended to be extremely helpful to the teacher in enlivening pupil learning through independent activites.

The second of the aforementioned works is intended to assist pupils in assimilating biological subject matter and to develop logical thinking. It consists largely of card-type assignments calling for the use of various knowledge resources: texts, tables, drawings, natural objects.

Expanding the pupil's horizons in biology is the purpose of the anthology entitled Khrestomatiya po obshchei biologii (compiled by O.V. Kazakova, L.S. Korotova and Z.A. Mokeeva, Prosveshchenie, 1970). This collection is designed both for classroom use and for out-of-class reading as a source of supplementary material related to all of the chapters of the basic textbook. The anthology contains extracts from the works of major Soviet and foreign scientists on various aspects of biology.

Its articles contain interesting material on all of the problems of biological science covered within the general biology course.

A careful look at the assortment of publications designed to help both pupil and teacher concerned with zoology and general biology provides an indication of the wealth of methodological and study literature available. In addition to the specialized works for each subject within the overall biology course there are also general works such as Vneklassnaya rabota po biologi (Out-of-Class Work in Biology) (by A.I. Nikishov, Z.A. Mokeeva, E.V. Orlovskaya and A.M. Semenova, Prosveshchenie, 1980) whose purpose is to increase the effectivenes of out-of-class work on this subject. The theory and specific methods of nature protection are dealt with in the book Okhrana prirody v shkol'nom kurse biologii (Nature Protection as part of the School Biology Curse) (by I.D. Zverev, A.N. Zakhlebnyi and I.T. Suravegina, Prosveshchenie, 1977). The problem of obtaining and using various learning aids and resources is discussed in Kabinet biologii (The Biology Room) (by D. I. Traitak, Prosveshchenie, 1976). The book Uchebno-optnye raboty na prishkol'nol uchastke (Experimental work by Pupils on the School Plot) (by M. A. Paporkov; Prosveshchenie, 1980) helps to organize study and practical activities by pupils taking part in the growing of plants on the school experimental plot.